

# Four new representatives of the genus *Allocyclops* Kiefer, 1932 from semi-consolidated subsoil aquifers in Benin (Copepoda, Cyclopoida, Cyclopidae)

Frank Fiers<sup>1,2</sup>, Moïssou Lagnika<sup>3</sup>

**1** Current address: Royal Belgian Institute of Natural Sciences, Vautierstraat 29, B-1000 Brussels, Belgium

**2** “Emil Racoviță” Institute of Speleology, Roman Academy, Clinicilor 5, PO Box 58, Cluj-Napoco, Romania

**3** Département de Zoologie, Faculté des Sciences et Techniques, Université d'Abomey-Calavi, 01 BP: 526, République du Bénin

Corresponding author: Frank Fiers ([frank.fiers@naturalsciences.be](mailto:frank.fiers@naturalsciences.be))

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## Abstract

Several species of cyclopoid copepods were collected from improved and unimproved hand-dug-wells in the Republic of Bénin over the years 2009–2014. Fifty five wells located in seven different districts were sampled: 15 wells in the district of Pobè (Department Plateau) and 1 well in Kétou (Department Plateau), 4 wells in Porto-Novo District (Department Ouémé) and, 15 wells in Lokossa District (Department Mono), 18 wells in Parakou District (Department Borgou), 1 well in Abomey-Calavi District (Department Atlantique) and 1 in Zogbodomè District (Department Zou). Among them, 4 new species of the genus *Allocyclops* Kiefer, 1932 were found and are described herein: *Allocyclops spinifer* sp. n., *A. nudus* sp. n., *A. pilosus* sp. n. and *A. sakitii* sp. n. They are compared with the three African species previously described. *Allocyclops* appears to be a sub-Saharan taxon specialized to thrive in the variable environment of subsoil aquifers in laterite deck beds. An identification key to the 7 different African *Allocyclops* species is provided.

## Keywords

Copepoda, Cyclopidae, subterranean, Bénin, new species, key, laterites



## Introduction

Within the context of a research program in the Republic of Bénin on the biodiversity of the subterranean realm in relation to water quality, pollution vulnerability and local use 48 wells were regularly sampled over a period of one year. Seven wells located in the close vicinity of the monitored wells were occasionally visited. Six of the seven areas are located in the drainage basin of the Ouémé: the area of Parakou in the north of the basin and the area of Kétou, Zogbodomé, Pobè, Abomey-Calavi and Porto-Novo in the south. The seventh study area, the district of Lokossa, belongs to the lower part of the Mono-Couffo drainage basin (see Fig 1). Physico-chemical characteristics of the Pobè and Parakou wells have been published (Lagnika et al. 2014a; 2014b). Analyses of the other regions are currently under study.

The Republic of Bénin, a country 650 km long and 325 km at its widest, in South-West Africa is a sub-Saharan savannah region enduring a tropical climatologic regime: humid in the south, semi-arid in the north (Kottek et al. 2006; Peel et al. 2007). The principal rainy season spans from April to late July. A less intense rainy period is active in the southern part of the country from late September to November. The dry seasons are from December to April and from late July to early September. Wells, dug in the thick laterite deck beds, are of vital importance for the communities during the eight months of drought. They also provide possibilities to study various aspects of this subterranean habitat and the local human impact on this extreme variable environment (Bonsor et al. 2013).

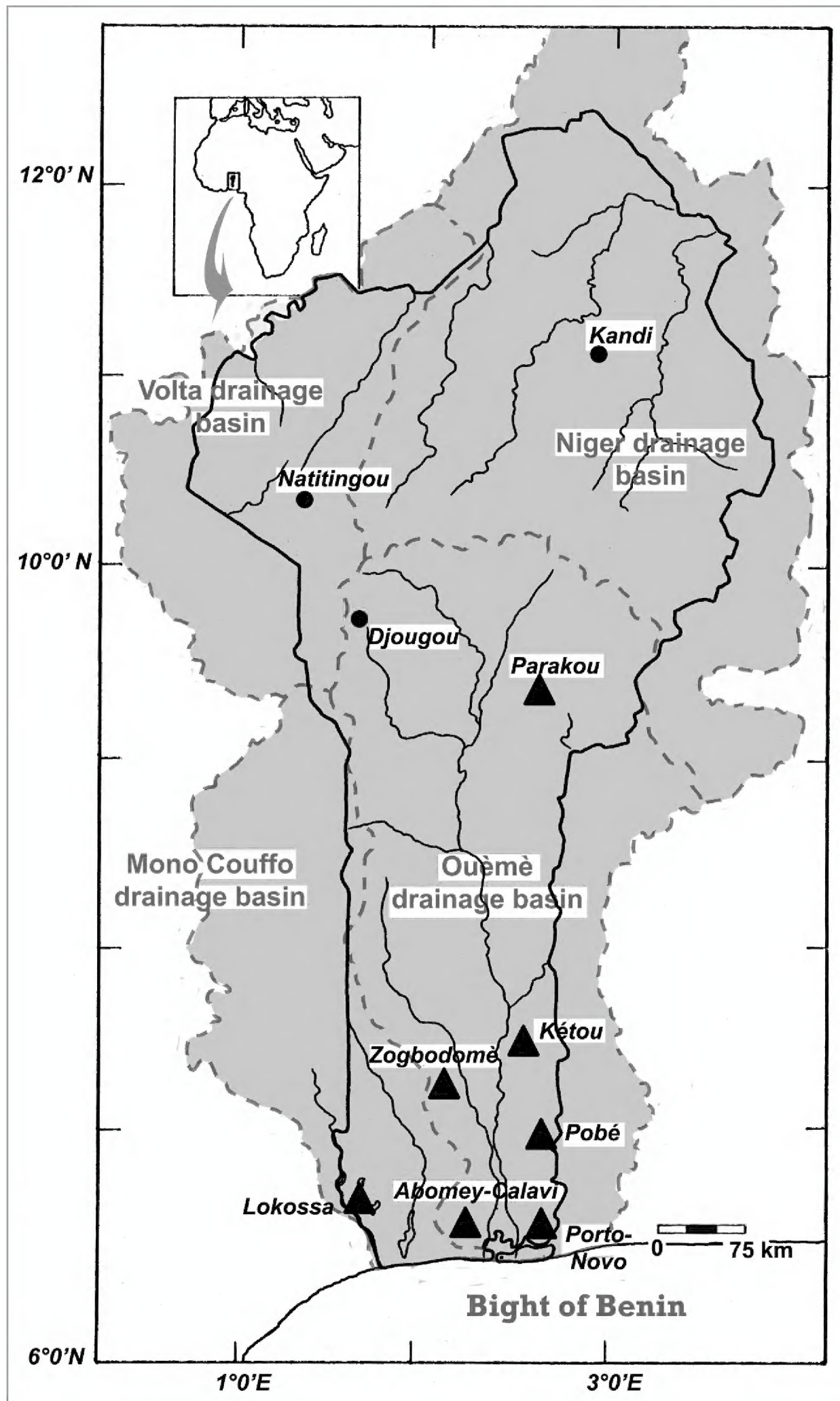
African continental waters have been a very attractive study subject in zooplankton research. Large regions, however, of this vast continent remain unexplored (Dussart 1980). This is particularly true in regards of the fauna thriving in subsoil aquifers for which certain taxonomic groups are ignored because of inadequate sampling and, mainly, the lack of specialists (Boutin et al. 2011; Tuekam Kayo et al. 2012).

Among the copepods collected during this intensive study (i.e. mostly representatives of *Afrocylops* Sars, 1927, *Thermocylops* Kiefer, 1927, *Mesocylops* Sars, 1914) no less than four different species which undoubtedly belong to the cyclopoid genus *Allocyclops* were detected. They are described herein and compared with the 3 other African *Allocyclops* previously known.

## Material and methods

In the following Tables 1–4 location and well characteristics are summarised (italics refer to the entries in the tables): “Total depth” of the well from ground level; “Ø” diameter of the well at ground level; “Water-level fluctuation”: difference between highest level and lowest level of the water column; “Wall characteristics” differentiate the wells as either a hand-dug well with un-cemented “*natural*” walls, or “*cemented*” i.e. constructed by cemented concrete rings with the lower parts perforated; “Well closure” refers to the protection from superficial influences: wells can left unprotected and are “*open*” or closed by a pave “*slab*”, corrugated “*iron*” or “*wood*”; “Principal use”: “*potable*” means exclusively used as drinking





**Figure 1.** Map of Bénin indicating the study areas (black triangles): Lokossa stands for 15 sampled wells, Porto Novo for 4 sampled wells, Pobé for 15 sampled wells and Parakou for 18 sampled wells. Grey dashed lines contour the limits of the 4 different drainage basins, from [http://eaubenin.bj/docs/Bassins\\_Versants/Atlas\\_Hydrographique\\_Rapport\\_final.pdf](http://eaubenin.bj/docs/Bassins_Versants/Atlas_Hydrographique_Rapport_final.pdf) (accessed November 2014).



**Table 1.** Sample localities and principal well characteristics in the district of Lokossa: presence of *Allocclops* species (dark grey background), other copepods (light grey background) and absence of Cyclopoida (white background).

Station	Total depth (m)	Ø (m)	Water level fluct. (m)	Wall character.	Well closure	Principal use	Location
P1	31,90	2,00	1,25	cemented	slab	potable	06°42'29.5"N, 01°48'11.8"E
P2	41,30	1,45	3,00	cemented	slab	potable	06°42'29.2"N, 01°48'11.9"E
P3	46,15	2,00	4,80	cemented	slab	potable	06°45'24.9"N, 01°49'11.7"E
P4	27,75	2,00	5,00	cemented	slab	potable	06°42'41.0"N, 01°44'46.7"E
P5	14,10	1,20	6,30	natural	open	potable	06°43'12.5"N, 01°44'02.7"E
P6	13,15	1,10	3,70	natural	open	potable	06°43'24.8"N, 01°44'39.2"E
P7	4,45	1,00	2,00	cemented	iron	domestic	06°38'22.8"N, 01°42'54.7"E
P8	5,00	1,45	0,50	cemented	slab	domestic	06°39'01.3"N, 01°40'32.1"E
P9	5,60	0,90	1,20	cemented	open	domestic	06°38'43.2"N, 01°42'26.8"E
P10	11,65	2,10	2,90	cemented	slab	domestic	06°40'03.5"N, 01°47'43.4"E
P11	10,70	0,90	2,10	natural	open	domestic	06°38'54.6"N, 01°46'47.6"E
P12	4,80	1,40	3,70	cemented	open	domestic	06°38'14.8"N, 01°46'54.3"E
P13	5,70	1,20	2,60	cemented	slab	domestic	06°41'29.0"N, 01°39'02.2"E
P14	8,85	2,00	6,35	cemented	slab	domestic	06°42'50.1"N, 01°38'17.8"E
P15	2,80	1,30	0,50	natural	open	domestic	06°43'04.1"N, 01°40'59.8"E

**Table 2.** Sample localities and principal well characteristics in the district of Parakou: presence of *Allocclops* species (dark grey background), other copepods (light grey background) and absence of Cyclopoida (white background).

Station	Total depth (m)	Ø (m)	Water level fluct. (m)	Wall character.	Closure	Principal use	Location
A1	7,78	1,2	1,18	cemented	iron	potable	09°16'22.7"N, 02°34'54.7"E
A2	6,95	1,05	0,85	cemented	open	domestic	09°19'40.3"N, 02°37'28.8"E
A3	5,9	1,25	1,15	natural	iron	domestic	09°20'53.9"N, 02°36'44.0"E
A4	13,15	1,5	4,35	cemented	iron	potable	09°18'42.1"N, 02°36'07.6"E
A5	8,4	1,2	3,1	natural	open	domestic	09°20'51.8"N, 02°36'14.8"E
A6	8,85	1,2	0,2	cemented	open	domestic	09°20'18.7"N, 02°37'36.3"E
B1	7,9	0,9	3,5	cemented	iron	potable	09°19'57.2"N, 02°39'40.6"E
B2	6,6	1,45	0,8	cemented	iron	potable	09°19'55.2"N, 02°39'40.5"E
B3	7,5	1,4	1,6	natural	slab	domestic	09°20'03.5"N, 02°37'47.2"E
B4	8,0	1,2	3,1	cemented	open	domestic	09°20'08.1"N, 02°37'45.4"E
B5	10,45	1,15	5,95	natural	open	domestic	09°20'18.0"N, 02°37'51.1"E
B6	16,15	1,4	10,55	cemented	iron	gardening	09°21'33.4"N, 02°38'32.4"E
C1	8,8	1,1	2,1	cemented	iron	domestic	09°23'28.7"N, 02°37'21.4"E
C2	14,2	1,8	5,5	cemented	iron	potable	09°23'05.5"N, 02°37'23.2"E
C3	10,8	1,2	5,8	cemented	iron	potable	09°21'58.4"N, 02°37'30.6"E
C4	5,5	1	0,9	natural	open	domestic	09°21'45.4"N, 02°37'46.6"E
C5	12,85	2	7,25	cemented	iron	potable	09°21'56.9"N, 02°36'41.2"E
C6	11,2	1,1	5,3	cemented	slab	potable	09°21'01.7"N, 02°37'37.6"E



**Table 3.** Sample localities and principal well characteristics in the district of Pobè: presence of *Allocyclops* species (dark grey background), other copepods (light grey background) and absence of Cyclopoida (white background).

Station	Total depth (m)	Ø (m)	Water level fluct. (m)	Wall character.	Well closure	Principal use	Location
Pb1	17,30	1,40	2,00	natural	open	potable	06°58'57.3"N, 02°40'32.4"E
Pb2	36,08	1,40	3,70	cemented	slab	potable	06°58'57.1"N, 02°39'54.9"E
Pb3	40,80	1,40	3,60	cemented	slab	potable	06°58'49.7"N, 02°39'19.6"E
Pb4	50,50	1,45	3,20	cemented	slab	potable	06°57'48.1"N, 02°38'50.2"E
Pb5	16,20	1,50	2,90	cemented	slab	potable	06°59'13.6"N, 02°39'56.6"E
Pb6	19,60	1,05	17,45	cemented	wood	domestic	07°12'03.5"N, 02°36'04.4"E
Pb7	6,10	0,60	3,75	natural	iron	domestic	07°09'28.7"N, 02°39'09.2"E
Pb8	26,27	1,50	7,30	cemented	open	domestic	07°02'10.1"N, 02°42'16.7"E
Pb9	19,25	1,40	4,65	cemented	wood	potable	07°09'23.5"N, 02°44'09.5"E
Pb10	17,60	1,60	5,75	cemented	open	potable	07°09'18.2"N, 02°44'10.6"E
Pb11	13,90	1,10	7,45	natural	iron	domestic	07°08'59.4"N, 02°45'02.1"E
Pb12	14,90	1,25	1,20	cemented	slab	potable	06°58'05.0"N, 02°41'47.9"E
Pb13	34,52	1,55	4,50	cemented	slab	potable	06°57'48.4"N, 02°42'10.1"E
Pb14	36,00	1,52	2,20	cemented	slab	potable	06°57'26.0"N, 02°42'25.9"E
Pb15	31,00	1,20	2,70	cemented	open	potable	06°57'39.6"N, 02°42'14.4"E

**Table 4.** Sample localities and principal well characteristics in the district of Porto-Novo: presence of *Allocyclops* species (dark grey background).

Station	Total depth (m)	Ø (m)	Water level fluct. (m)	Wall character.	Closure	Principal use	Location
AR	7,80	0,90	3,00	cemented	iron	domestic	06°29'04.2"N, 02°38'24.3"E
SA	7,00	0,90	2,00	natural	open	domestic	06°29'02.4"N, 02°38'26.0"E
LB	10,50	0,85	2,85	natural	open	domestic	06°29'05.7"N, 02°38'25.3"E
AH	4,00	1,00	2,50	natural	iron	domestic	06°29'18.8"N, 02°38'14.8"E

water, “domestic” when the water is used for all purposes, and “gardening” when used only for private household gardens. Sample dates are provided with the description of each species. Detailed information on the different drainage basins was extracted from the reports made available through the “*Direction Générale de l'Eau*” (2008).

The occasionally sampled wells: at Abomey-Calavi located adjacent to the university grounds in the village of Zogbadjè (11.75 m deep, 1 m Ø, 2.10 mean water level, natural walls, left open, domestic purposes; well location: 6°25'32.2"N, 002°20'17.2"E; Department Atlantique); village well at Kéwi in the district of Kétou (open, natural, abandoned well in secondary forest; district centre: 7°21'29"N, 2°36'27"E; Department Plateau) and well at Zogbodomè situated close to the main road (open natural domestic use; district centre 7°05'N, 2°06'E; Department Zou).



Biological samples of the water column were taken with a Cvetkov plankton net (funnel 200 µm mesh size, 150 µm below valve). Baited traps were used to collect bottom dwelling animals. Total depth, diameter (Ø), and mean water depth were measured with a decametre and the exact location with a Garmin® GPS60. Samples were fixed at the spot adding 100 ml of a 7% formaldehyde solution. Sorted out at the laboratory of the Zoology Department of the Abomey-Calavi University, each taxon has been stored separately and preserved in 70% ethanol.

Copepods were first observed in temporary slides (mounted in glycerol). Dissected animal parts are mounted on permanent slides in glycerol, the cover glasses sealed with a polyurethane varnish. Preserved specimens are stored in 75% buffered ethyl alcohol (with 5–10% glycerol). All material is stored in the Crustacea collection of the Royal Belgian Institute of Natural Sciences and inventoried with acc. nr RBINSc COP #. Observations and illustrations were made on a Leitz Diaplan phase contrast microscope equipped with a camera lucida. Abbreviations used in the descriptions: Aesth, aesthetasc; CIV-CV, copepodid stages 4 and 5; EXO, END, exopodite and endopodite, respectively; L/W ratio, length/width ratio; armature distribution of the leg ramal segments: Roman numerals refer to spines, Greek numerals to setae.

## Taxonomy

### Family Cyclopidae Rafinesque, 1815

#### Genus *Allocyclops* Kiefer, 1932 *amend.* Fiers, 2012

#### *Allocyclops spinifer* sp. n.

<http://zoobank.org/FE0625DC-8A08-45A3-AC41-44566A1C2426>

Figs 2, 3, 4A, B, I, 5A–C, 6

**Type locality.** Ishèko (Pobè District, Ouémé drainage basin), Well Pb5: West from Pobè center along the principal road to Kétou District (details in Table 3).

**Type material.** Female holotype, dissected and mounted on 3 slides (RBINSc COP 10.304A–C), allotype male, dissected and mounted on 3 slides (RBINSc COP 10.305A–C), 1 female paratype dissected on 2 slides (RBINSc COP 10.306A–B) and 4 females, 5 males and 4 juveniles preserved (RBINSc COP 10.307), all collected 26/07/2012; additional paratypic material: 3 females, 4 males, 5 juveniles (preserved material RBINSc COP 10.353), topotypic, collected 16/04/2013.

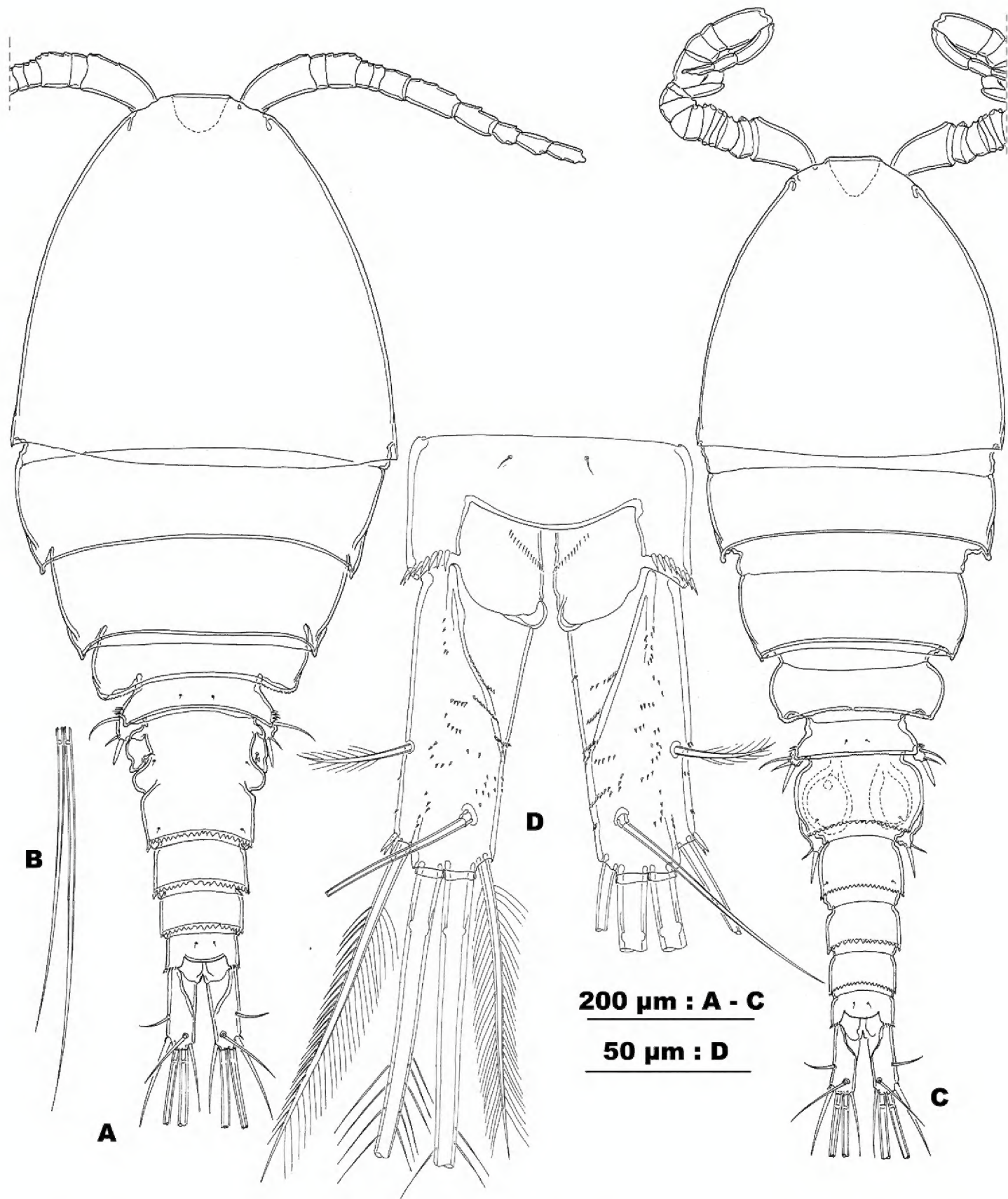
**Etymology.** derived from the Latin words *spinula* and *ferre*, respectively meaning small thorn and to carry, and referring to the spinular ornamentation on pediger 5, on leg 4 and on the caudal rami.

#### **Additional material.**

(1) Pobè District, Ouémé drainage basin:

- Well Pb6: 07/02/11: 6 ♀♀, 2 ♂♂ and 2 CV copepodids (♀ dissected RBINSc COP 10.308A–C, preserved material RBINSc COP 10.309); 27/11/2012:





**Figure 2.** *Allocyclops spinifer* sp. n. **A** habitus in dorsal view **B** principal setae of left caudal ramus **C** habitus in dorsal view **D** anal somite and caudal rami, dorsal view. (Female RBINSc COP 10.304: **A**, **B**, **D**; male RBINSc COP 10.305: **C**).

19 ♀♀, 5 ♂♂, 1 CIV & 1 CV ♀ (CV dissected RBINSc COP 10.386A-B, preserved material RBINSc COP 10.327); 04/03/2013: 21 ♀♀, 11 ♂♂, 5 juveniles (preserved material RBINSc COP 10.339); 26/11/2012: 2 ♀♀ (preserved material RBINSc COP 10.377); 20/09/2013: 9 ♀♀, 2 ♂♂ (preserved material RBINSc COP 10.376).



- Well Pb12: 24/07/2012: 3 ♀♀, damaged (preserved material RBINSc COP 10.328).

(2) Zogbodomè District, Ouémé drainage basin:

- Well Zogbodomè: 21/10/2009: 2 ♀♀, 1 ♂ (preserved material RBINSc COP 10.387).

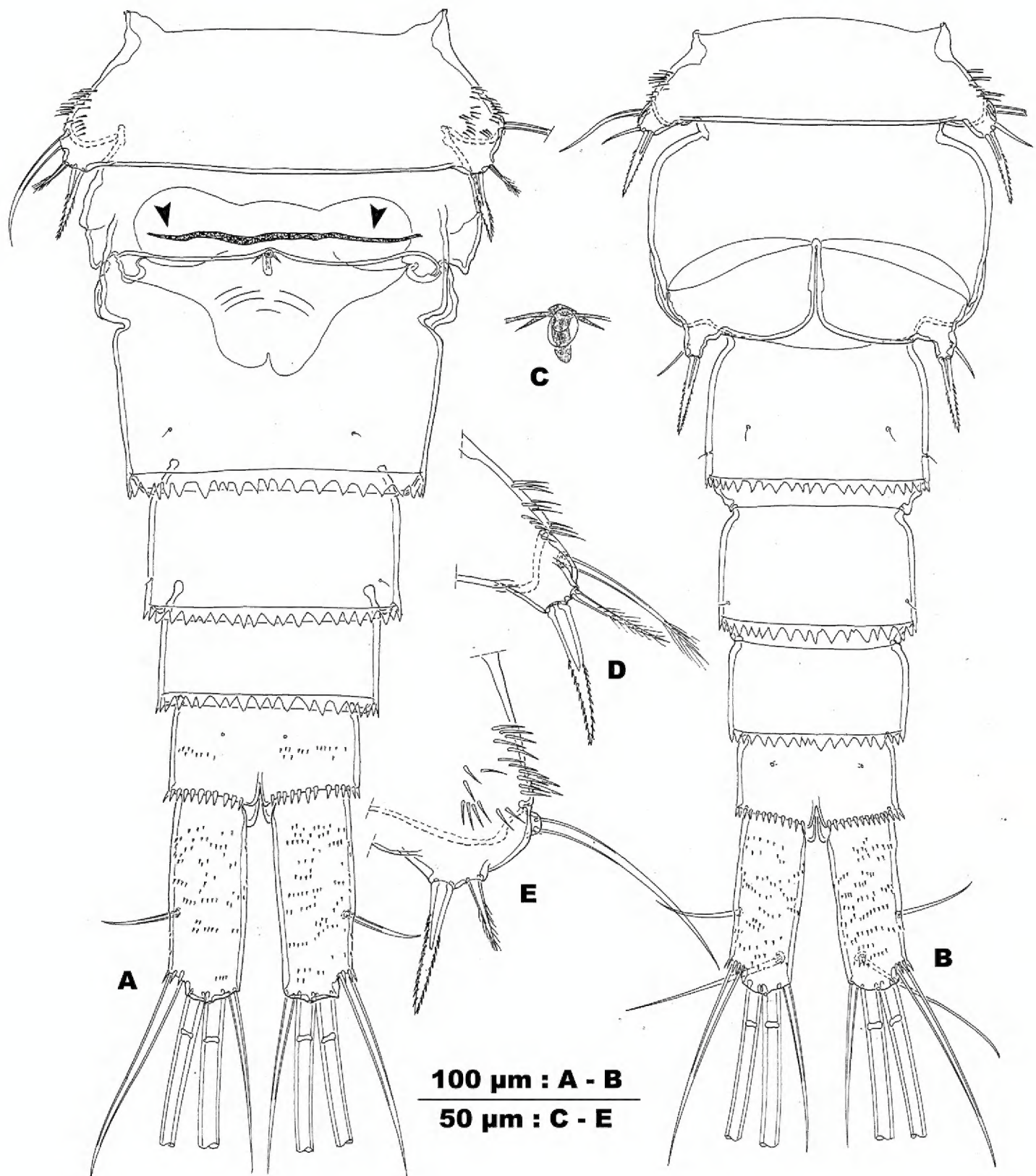
**Description.** *Female.* Habitus (Fig. 2A) typically cyclopoid with prominent prosome, 1.6 times longer than urosome. Body length 1175 µm (holotype), ranging from 1075 to 1200 µm (n=5). Urosome rather narrow, compared to wide cephalothorax and pediger 2. Urosomite 1 (pediger 5) with cluster of long and rigid spinules on the lateral and ventrolateral surface (Fig. 3D). Genital double-somite widest in anterior third, with distinct constriction of lateral margins in anterior half and a L/W ratio: 1/1.25. Ventral surface with, in frontal third, a transverse undulate ridge parallel with lateral arms of genital complex (dotted line between arrows in Fig. 3A) and, caudally from copulatory pore, some crescent ridges. Posterodorsal fringe of prosomites 1–3 narrow and un-incised, of prosomite 4 and first urosomite narrow and discretely serrate. Posterior margin of genital double-somite and urosomites 4–5 wide and serrate, coarsely incised. Anal somite with smooth crescent operculum and large anal sinus. The latter with an oblique row of minute and slender spinules on either side of the anal slit. Posterior margin of anal somite with uninterrupted row of spinules. Dorsal and lateral surface of urosomites adorned with minute, hardly visible spinules. Ventral surface of anal somite with an irregular pattern of slightly larger spinules.

Caudal rami (Fig. 2D) cylindrical, 2.7–3.0 times longer than wide, with distinct triangular depression in anterior half of medial margin. Anterolateral seta short, pinnate, and inserted in posterior half, without spinules at insertion. Distolateral element slightly longer than ramus (ratio 1.2–1.3/1) and longer than medial terminal element (ratio 1.2–1.4/1). Distolateral element with widely spaced long and slender spinules along outer side of stem, with widely spaced setules along inner side; spinules present near its insertion. Medial element as long as caudal ramus, and pinnate. Dorsal seta, articulating on small basal part, shorter than ramus (ratio 0.8–0.9/1). Principal terminal caudal setae pinnate, with breaking plane present in both. Surface of rami with irregular and diffuse pattern of minute spinules on dorsal and ventral side, triangular anteromedial depression clearly delimited dorsally.

Antennule 11-segmented, not reaching beyond cephalothorax, and having the typical armature distribution *i.e.*: 1(8)-2(4)-3(6)-4(2)-5(2)-6(2)-7(3)-8(2+Aesth.)-9(2)-10(2+Aesth.)-11(7+Aesth). First segment with crescent row of slender spinules in proximal half (Fig. 4A). Aesthetasc on segment 8 half as long as accompanying seta, linguiform, and reaching just beyond distal margin of segment 8. Aesthetasc on segment 10 filiform, shorter than accompanying element and extending to middle of terminal antennular segment. Terminal aesthetasc tubular, slightly longer than segments 10–11 combined, and fused at base with seta; both equally long (Fig. 4B).

Antennal general aspect and armature as in *A. cavicola*: *i.e.*: 4-segmented, short exopodal seta, 2 abexopodal setae, first endopodite segment with 1, second one with 9, and ultimate segment with 7 elements. Frontal surface of coxobasis (Fig. 5A) with 2





**Figure 3.** *Allocyclops spinifer* sp. n. **A** urosome in ventral view **B** urosome in ventral view **C** copulatory pore and duct **D** leg 5 and lateral part of pediger, in ventral view **E** leg 5 and lateral side of pediger in ventral view. (Female RBINSc COP 10.304: **A**, **C**; RBINSc COP 10.306: **E**; male RBINSc COP 10.305: **B**, **D**).

rows of coarse spinules parallel to outer margin (proximal one with 10–12, distal one with 9–10 spinules) and short proximal transverse row of tiny spinules near abexopodal margin. Caudal surface (Fig. 5B, C) with 3 clusters of long and slender spinules in proximal half: 2 clusters near outer margin, 1 near inner margin.

Mandible, maxillule and maxilliped as in *A. cavicola*. General aspect of maxilla as in *A. cavicola*. Medial claw of maxillary basis (Fig. 4I) long and blunt, armed with 4 large teeth increasing in length medially. Accessory seta as long as claw, serrate on both



sides in proximal half, on one side in distal half. Both elements on first endopodite segment with set of large spinules in middle. Distal half either smooth or with minute spinules along both sides of the stem. Terminal element on second endopodite segment articulating on segment, furnished with minute spinules along one side of the stem. Both lateral elements on second segment slender and naked.

Legs 1–4 protopodite (Fig. 6A, C, D, F, G). Praecoxa of legs 1–3 with short row of slender spinules along distal margin close to outer edge. Praecoxa of leg 4 smooth. Outer part of coxa with 2 (legs 1–3) or 3 (leg 4) short rows of spinules on frontal surface. Coxal caudal surface of legs 1–3 with set of spinules near proximal outer edge (see ex. for leg 2: Fig. 6D). Medial coxal seta of legs 1–4 pinnate and reaching beyond proximal endopodite segment. Intercoxal sclerites unadorned on both sides. Lateral distal edges crescent without ornamentation. Mediodistal region concave (legs 1–3: Fig. 6B) or nearly straight (leg 4). Inner edge of leg 1 basis crescent, of legs 2–4 produced in sharp triangular process. Medial margin hairy in legs 1–3, naked in leg 4. Inner element on leg 1 basis present, serrate and reaching beyond proximal endopodite segment, but not beyond middle of distal segment. Outer element on basis of the legs setiform: longest on leg 1 basis, shortest one on basis of leg 2.

Legs 1–4 with 2-segmented rami (Fig. 6A, C, F, G). Exopodite and endopodite equally long. Rami with the following armament distribution:

	EXO	END
Leg 1	I,1 - III,2,3	0,1 - 1,I+1,3
Leg 2	I,1 - III,I+1,4	0,1 - 1,I+1,4
Leg 3	I,1 - III,I+1,4	0,1 - 1,I+1,4
Leg 4	I,0 - II,I+1,4	0,1 - 1,II,3

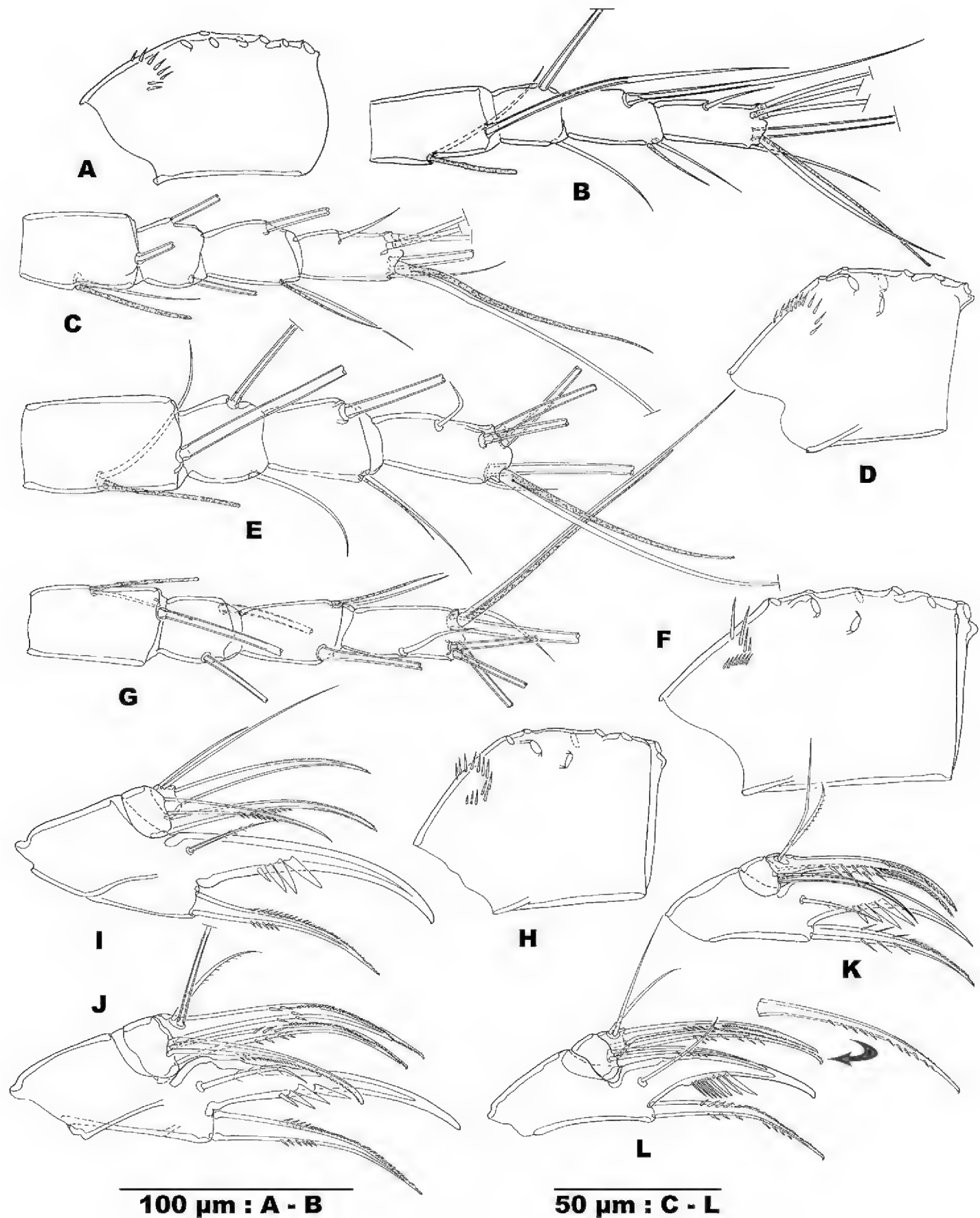
Outer distal edge of second endopodite segment of legs 1–3 distinctly protruded, of leg 4 small and as large as inner one. Frontal and caudal surface of leg segments of legs 1–2 and frontal surface of leg 3 unadorned. Caudal surface of distal endopodite segment of leg 3, and frontal and caudal surface of leg 4 segments with diffuse pattern of tiny spinules.

Caudal surface of proximal endopodite segment of leg 4 inflated. Distal endopodite segment of leg 4 twice as long as wide with inner terminal spine as long as segment. Outer terminal spine slightly longer than half inner one (ratio: 0.55–0.56). Inner terminal spine set with long slender spinules. Outer subdistal and inner setae, equally long, not reaching noticeably beyond longest (outer) terminal spine.

Leg 5 (Fig. 3E) confluent with pediger, represented by narrow crescent expansion. Ancestral basal segment represented by long pinnate element, and ancestral distal segment marked by narrow truncate elevation, bearing 2 elements: setiform outer one, spiniform medial one, the latter twice as long as the former.

Leg 6 vestiges located laterally with 3 elements: dorsal one short and setiform, middle and ventral one dwarfed, blunt triangular, with hyaline appearance. Valves unadorned. Copulatory pore located midventrally in anterior third of somite, leading to U-shaped duct (Fig. 3C). Anterior receptacle expanded with undulate frontal margin. Posterior receptacle produced caudally extending to middle of double-somite,





**Figure 4.** *Allocyclops spinifer* sp. n. **A** antennular segment 1 **B** antennular segments 8–11; *A. pilosus* sp. n. **C** antennular segments 8–11 **D** antennular segment 1; *A. nudus* sp. n. **E** antennular segments 8–11 **F** antennular segment 1; *A. sakitii* sp. n. **G** antennular segments 8–11 **H** antennular segment 1; *A. spinifer* sp. n. **I** maxillary basis and endopodite; *A. nudus* sp. n. **J** maxillary basis and endopodite; *A. pilosus* sp. n. **K** maxillary basis and endopodite; *A. sakitii* sp. n. **L** maxillary basis and endopodite (RBINSc COP 10.304: **A, B, I**; COP 10.310: **C, D, K**; COP 10.367: **E, D, J**; COP 10.253: **G, H, L**).



bilobed. Lateral arms (= narrow canal-like rim extending from copulatory duct to genital aperture) straight.

**Male.** Habitus (Fig. 2C) as in female, but with narrower prosome and 6-segmented urosome. Body length: 1000  $\mu\text{m}$  (allotype), ranging from 807–1000  $\mu\text{m}$  ( $n=5$ ). Integumental ornamentation, fringe structure and L/W ratio of caudal rami as in the female (2.7–3.0/1). Armature: distolateral element 1.27–1.30 times longer than ramus, terminal medial element nearly 0.9–1.0 times ramal length, dorsal seta as long as ramus.

Antennule as described for *A. cavicola*: i.e. 16-segmented with the following armature distribution: 1(8+3 Aesth.)-2(4)-3(2)-4(1)-5(2)-6(2)-7(2)-8(2)-9(2+Aesth.)-10(2)-11(2)-12(2)-13(1+Aesth.)-14(4)-15(3)-16(11+Aesth.). Aesthetascs on segment 1, 9 and 13 long, narrow and linguiform. Mouthparts as in the female. Legs 1–4 with general structure and armature as in the female, but terminal segment of endopodites slightly narrower (see ex. for leg 3: Fig. 6H) and leg 4 proximal endopodite segment not expanded caudally.

Leg 5 (Fig. 3D) with expansion representing distal segment more accentuated than in female. Proportional lengths of armament as in the female. Spinule ornamentation on lateral and ventral surface of pediger less dense than in the female.

Leg 6 (Fig. 3B) represented as a large, unadorned, valve with outer distal edge distinctly produced bearing 2 elements: outer one setiform, half as long as medial spiniform element.

**Variability.** Animals from Well Pb 6 collected on 07/02/2011 are smaller with the body length of the females ranging from 875 to 1009  $\mu\text{m}$ , that of the males between 890–895  $\mu\text{m}$ . They display shorter caudal rami (L/W ratio 1/2.6–2.7) with slightly longer setae: distolateral one 1.3–1.4 times longer than the ramus, and medial terminal element 1.1–1.3 times longer than ramus. In all other respects they resemble *A. spinifer* sp. n. as described above.

### ***Allocyclops pilosus* sp. n.**

<http://zoobank.org/FA418D62-E64F-417A-A11E-8B5D3B147922>

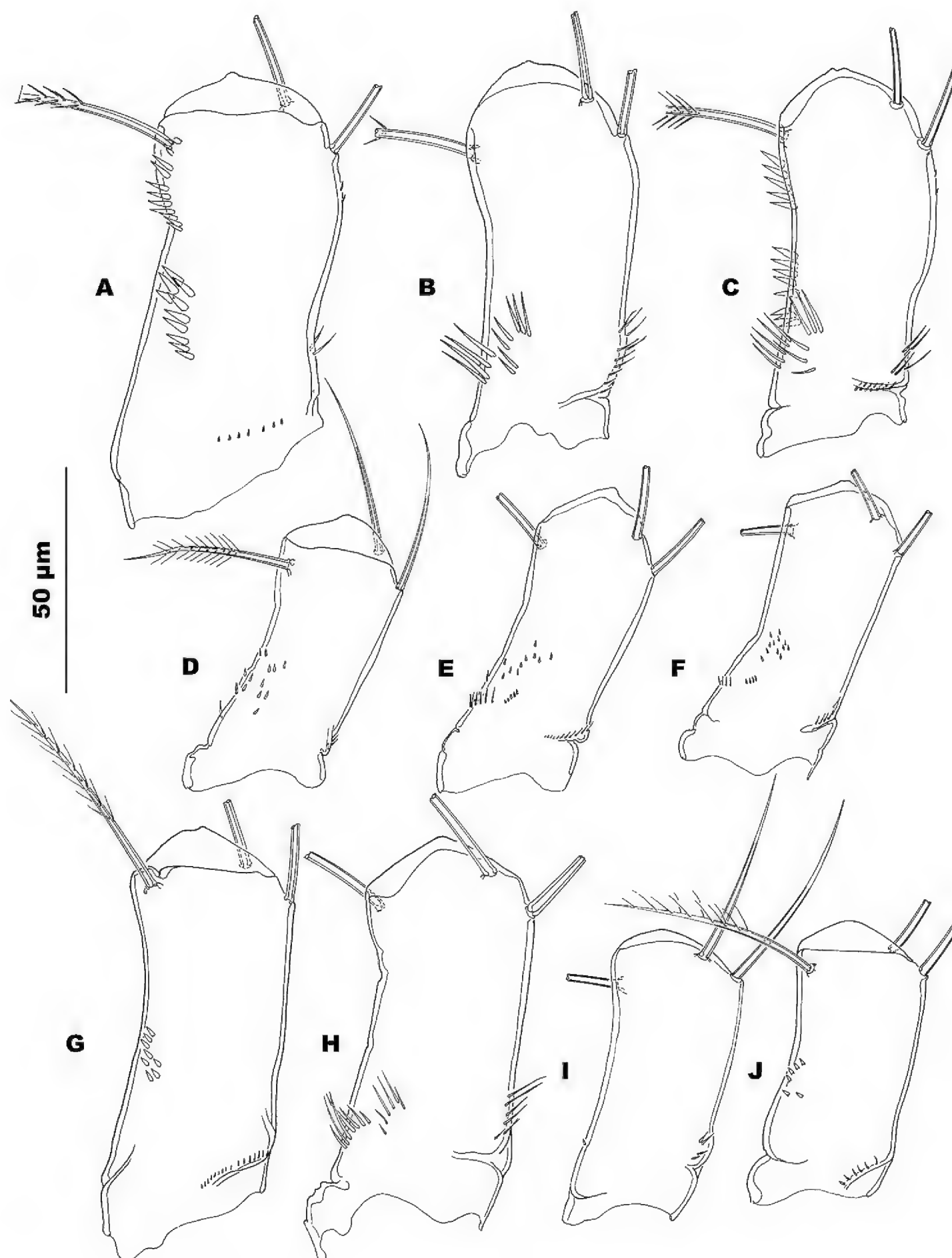
Figs 4C, D, K, 5D–F, 7, 8, 9

Syn. *Allocyclops* sp. [*partim*] in Lagnika et al. 2014b

**Type locality.** Guéma, Parakou District, Ouémé drainage basin: Well C2 (details in Table 2).

**Type material.** Female holotype, dissected and mounted on 3 slides (RNBNSc COP 10.313A–C), allotype male, dissected and mounted on 2 slides (RBINSc COP 10.312A–B), paratypes: 11 females and 2 males preserved in alcohol (RBINSc COP 10.314), all collected 07/03/2013; and additional (topotypic) paratypes collected on 13/02/2011: 4 females, 1 male, 1 juvenile; on 08/03/2013: 37 females, 15 males, 7 juveniles (preserved material RBINSc COP 10.340).





**Figure 5.** Antennary coxobasis: *Allocyclops spinifer* sp. n. **A** frontal view **B** caudal view **C** caudal view; *Allocyclops pilosus* sp. n. **D** frontal view **E** caudal view **F** caudal view; *Allocyclops nudus* sp. n. **G** frontal view **H** caudal view; *Allocyclops sakitii* sp. n. **I** caudal view **J** frontal view (RBINSc COP 10.304: **A**; COP 10.306B, COP 10.305: **C**; COP 10.310: **D, E**; COP 10.312: **F**; COP 10.3334, COP 10.367; COP 10.355: **I, J**).



**Etymology.** From the Latin word “*pilus*” meaning hair and refers to the rows of delicate hairs along the medial margin of the caudal rami.

**Additional material.**

(1) Parakou District, Ouémé drainage basin:

- Well A1: 10/07/12: 5 ♀♀, 1 CV juvenile ♀ (preserved material RBINSc COP 10.321);
- Well B6: 26-10-11: 1 ♀ (preserved material RBINSc COP 10.320); RBINSc COP 10.311);
- Well C6: 13/12/10: 11 ♀♀ (dissected ♀ RBINSc COP 10.316A-B, preserved material RBINSc COP 10.317; 29/10/2011: 33 ♀♀, 1 juvenile (preserved material RBINSc COP 10.342).

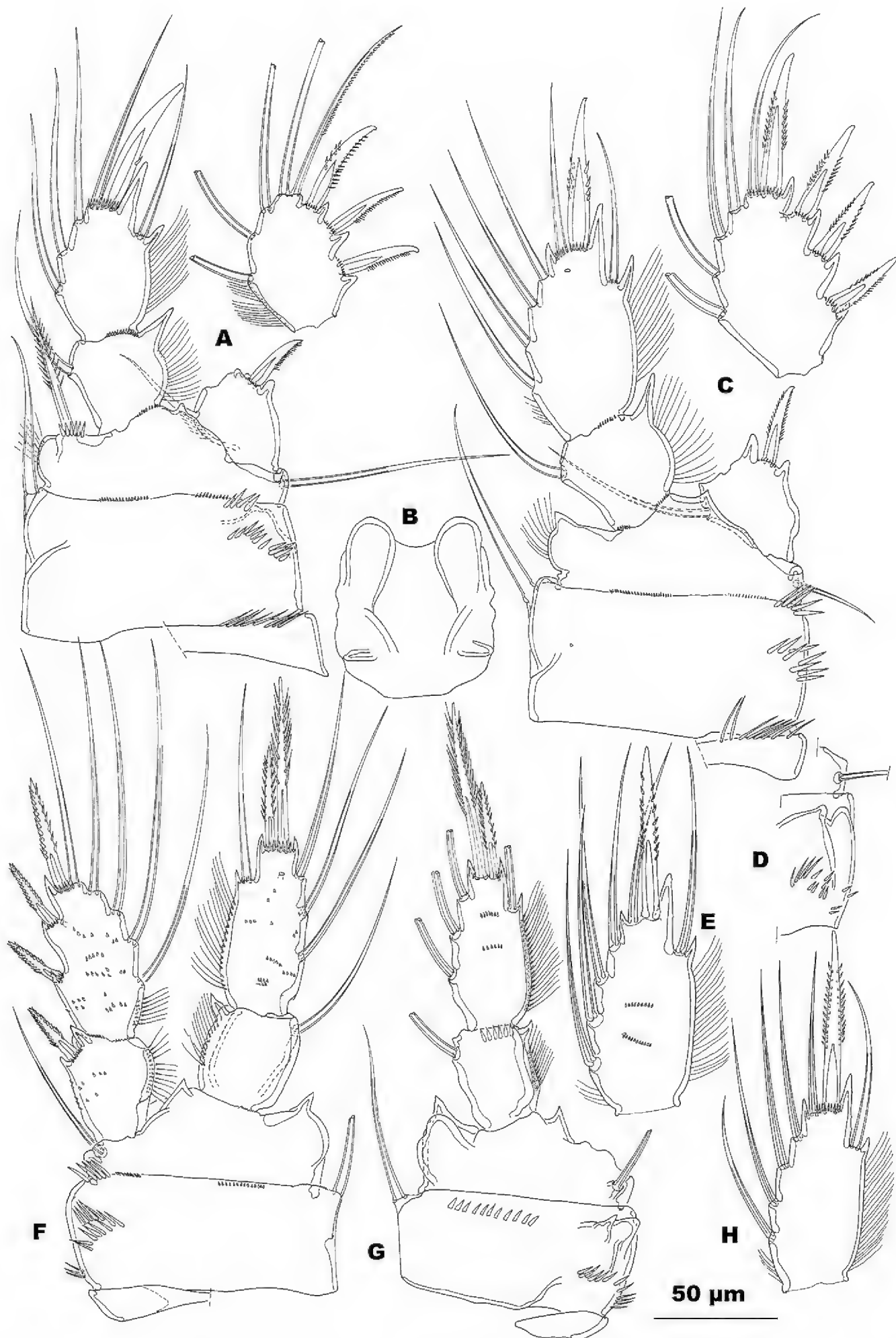
(2) Pobè, Plateau District, Ouémé drainage basin:

- Well Pb6: 07/02/11: 4 ♀♀ (preserved material RBINSc COP 10.332); 27/07/2012: 4 ♀♀, 2 ♂♂ (♀ dissected RBINSc COP 10.385A-B, preserved material RBINSc COP 10.336); 26/11/12 : 2 ♀♀ (preserved material RBINSc COP 10.374); 04/03/2013: 3 ♀♀, 3 ♂♂, 2 juveniles (preserved material RBINSc COP 10.345); 20/09/2013: 5 ♀♀, 1 CV copepodite (preserved material RBINSc COP 10.375);
- Well Pb7: 27/7/12: 15 ♀♀, 4 ♂♂ (dissected ♀ RBINSc COP 10.325A-B, preserved material RBINSc COP 10.326); 16/04/2013: 28 ♀♀, 2 ♂♂, 1 juvenile (preserved material RBINSc COP 10.346);
- Well Pb 8: July 2013: 2 juveniles (preserved material RBINSc COP 10.343);
- Well Pb 9: 17/04/2013: 2 ♀♀ (preserved material RBINSc COP 10.341);
- Well Pb10: 27/07/2012: 2 ♀♀ (preserved material RBINSc COP 10.347); 30/09/2012: 2 ♀♀, 2 ♂♂ (preserved material RBINSc COP 10.384); 25/11/2012: 3 ♀♀ (preserved material RBINSc COP 10.383);
- Well Pb11: 27/07/2012: 68 ♀♀, 3 ♂♂ (preserved material RBINSc COP 10.344); 30/09/2012: 387 F 5 CV females; 23/02/13: 3 ♀♀, 6 CIV juvenile ♀♀, 4 CV juvenile ♀♀ (dissected adult ♀♀ RBINSc COP 10.322A-C and COP 10.323A-C, preserved material RBINSc COP 10.324);

(3) Porto-Novo, Ouémé District, Ouémé drainage basin:

- Well SA: 01/01/10: 8 ♀♀, 1 CIV ♀ juvenile (dissected ♀ RBINSc COP 10.318A-B, preserved material RBINSc COP 10.319); 24/10/2010: 625 adult females and males (preserved material RBINSc COP 10.382);
- Well AH: 01/11/2009: 12 ♀♀ with body covered with stalked ectoparasites (preserved material RBINSc COP 10.329 and COP 10.330); 30/03/2013: 1 ♀ (preserved material, RBINSc COP 10.380); 31/01/2014: 6 ♀♀ 2 CV juveniles (preserved material, RBINSc COP 10.381);
- Well AR: 09/12/2010: 1 ♀ (material preserved RBINSc COP 10.331); June 2013: 1 ♀, damaged (preserved RBINSc COP 10.379);
- Well LB: 20/01/2014: 83 ♀♀ 5 ♂♂ 6 copepodites (damaged, material preserved RBINSc COP 10.373); 09/03/2014: 5 ♀♀ (material preserved RBINSc COP 10.374).





**Figure 6.** *Allocyclops spinifer* sp. n. **A** leg 1, frontal view **B** intercoxal sclerite of leg 1, frontal view **C** leg 2, frontal view **D** outer region of coxa and basis of leg 2, caudal view **E** distal segment of leg 3 endopodite, caudal view **F** leg 4, frontal view **G** leg 4 protopodite and endopodite, caudal view **H** distal endopodite segment of leg 3, frontal view. (Female RBINSc COP 10.306: **A, B, C, G**; female RBINSc COP 10.304: **D, F, E**; male RBINSc COP 10.305: **H**).



(4) Kéwi, Kétou District, Ouémé drainage basin:

- village well: 08/02/11: 17 ♀♀, 1 ♂ (preserved material RBINSc COP 10.315).

**Description.** *Female.* Body (Fig. 7A) typically cyclopid with prosome and urosome almost equally long. Prosome less prominent than in preceding species. Body length: 745  $\mu\text{m}$  (730–820  $\mu\text{m}$ ,  $n=5$ ). Laterocaudal expansion of urosomite 1 (pediger 5) accentuated by outwards directed leg 5 (Fig. 8A). Genital double-somite widest in anterior third, tapering caudally. Length/width ratio 1/1. Urosomites 4–5 parallel sided. Cephalothorax, metasomites and first urosomite with narrow and straight posterior fringe. Posterior fringe of genital double somite and urosomites 4–5 narrow and delicately serrate. Surface of somites smooth. Anal somite (Fig. 7D) with continuous row of spinules along posterior margin. Anal operculum crescent, not expanded. Anal sinus with single oblique row of minute spines on both sides.

Caudal rami (Fig. 7D) cylindrical with large mediodorsal triangular depression and 2.7 times as long as wide. Lateral anterior seta short, inserted at caudal end of median third. Distolateral element longer than ramus (ratio: 1/1.2–1.3), furnished with long slender and widely spaced spinules along outer side of stem, and widely spaced setules along medial side. Medial terminal element longer than distolateral one (ratio: 1/0.75) and ramus (ratio: 1/0.65). Breaking plane in both principal terminal setae present; each seta pinnate. Dorsal seta located in caudal third, near medial edge, articulating on short basal part and as long as medial terminal seta. Medial depression with two series of slim spinules (hairlike) arranged perpendicularly on principal axis of the rami. Posterolateral element with spinules at insertion, anterolateral one without.

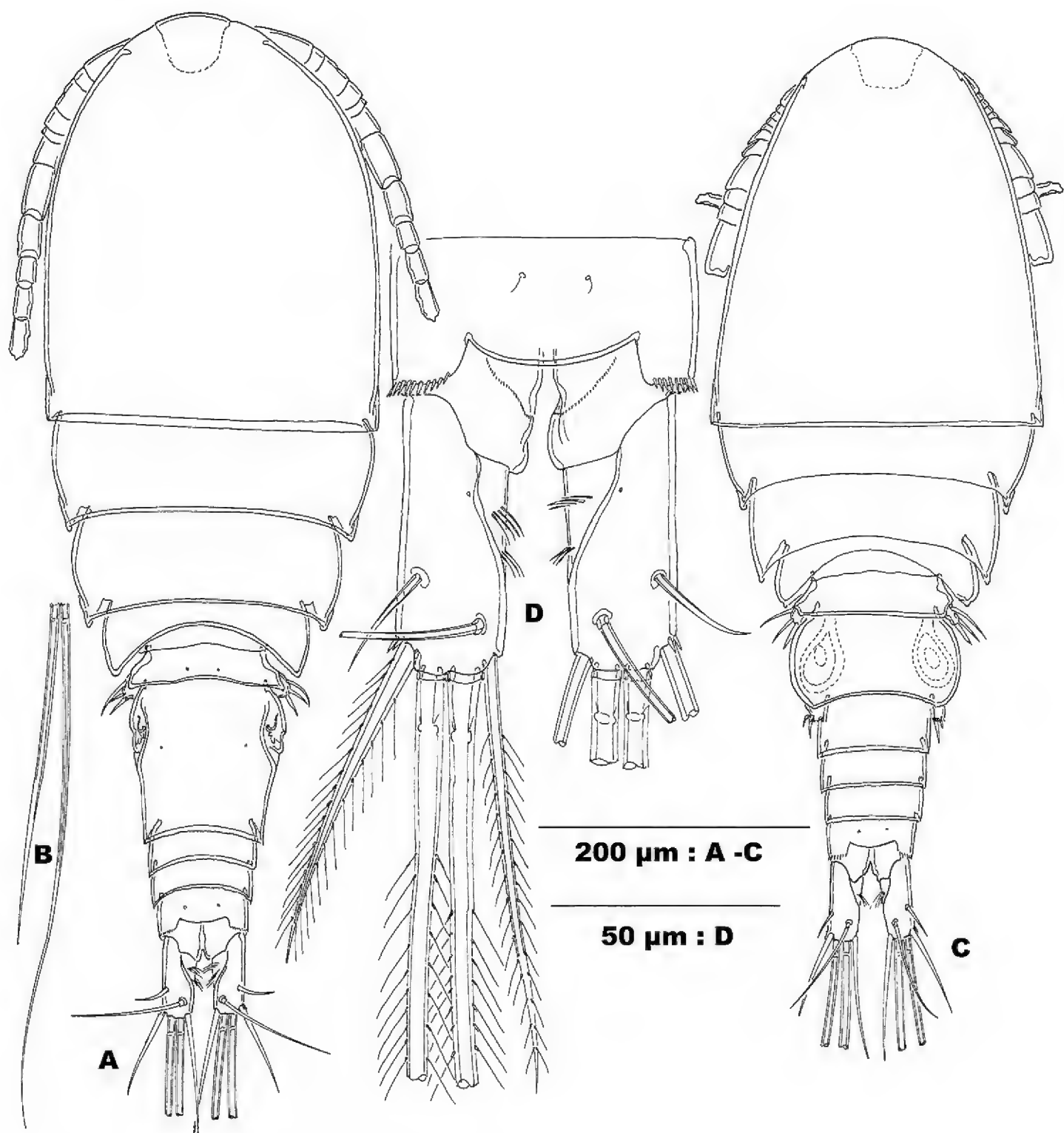
Antennule 11-segmented with typical armature distribution. First segment with crescent row of slender spinules in proximal half (Fig. 4D). Aesthetasc on segment 8 as long as accompanying seta, linguiform, and reaching almost to distal margin of segment 9. Aesthetasc on segment 10 filiform, shorter than accompanying element and reaching beyond middle of terminal antennular segment. Terminal aesthetasc as long as segments 9–11 combined, fused at base with seta. The latter longer than aesthetasc (Fig. 4C).

Antennal general aspect and armature as in *A. cavicola*. Frontal surface of coxobasis with diffuse pattern of minute spinules in proximal half on and near outer margin (Fig. 5D). Caudal surface with 3 short rows of tiny spinules in proximal half: 1 near outer margin, 1 below a diffuse distal cluster of tiny spinules, and 1 near inner margin (Fig. 5E, F).

Mandible, maxillule and maxilliped as in *A. cavicola*. General aspect of maxilla as in *A. cavicola*. Medial claw of basis rather short and sharp, furnished with 4 large teeth increasing in length medially (Fig. 4K). Accessory element as long as claw, furnished with widely spaced spinules in proximal half, densely serrate in distal half. First endopodite segment with one smooth and one serrate element. Terminal element on second endopodite segment confluent with segment, with long widely spaced spinules in proximal half and densely serrate in distal half.

Legs 1–4 protopodite (Fig. 9A, C, F, G). Praecoxa of legs 1–3 completely devoid of ornaments, of leg 4 with a short row of spinules along distal frontal margin, near outer edge. Both sides of the coxa of legs 1–3 unadorned, except for short rows of min-





**Figure 7.** *Allocyclops pilosus* sp. n. **A** habitus in dorsal view **B** principal caudal setae of left caudal ramus **C** habitus in dorsal view **D** anal somite and caudal rami in dorsal view (Female RBINS Sc COP 10.310: **A, B, D**; male RBINS Sc COP 10.312: **C**).

ute spinules along the frontal distal margin. Leg 4 coxa with some spinules on the outer distal frontal edge. Caudal surface of leg 4 coxa with 2 short rows of narrow spinules near the proximal outer caudal edge, and one median row parallel with distal margin. Intercoxal sclerites smooth on both sides, with crescent unadorned laterodistal expansions in legs 1–3 (see ex. Fig. 9B). Leg 4 intercoxal sclerite (Fig. 9H) with concave distal margin, lacking laterodistal expansions. Medial coxal element present in all legs, pinnate and rather short, reaching slightly beyond the distal edge of the basis in legs 1–3, being shorter in leg 4. Medial element on leg 1 basis serrate and long, reaching



to upper quarter of distal endopodite segment. Medial margin of leg 1 basis crescent and hairy. Outer seta of leg 1 basis longer than exopodite. Medial margin of legs 2–3 basis hairy, naked in leg 4. Distal inner edge of basis of legs 2–4 with short triangular expansion. Outer element on basis of leg 2 short, of legs 3–4 long.

Legs 1–4 with 2-segmented rami. Exopodite and endopodite of the legs equally long (Fig. 9A, C, F, G). Armament distribution and general aspect of segments as in preceding species. Segments devoid of ornamentation on frontal and caudal surface. Proximal endopodite segment of leg 4 flat, not expanded caudally. Leg 4 distal endopodite segment 2.2–2.3 times longer than wide with inner terminal spine slightly shorter than segmental length. Outer terminal spine half as long as inner one. Outer subdistal seta reaching to or just beyond tip of inner terminal spine, inner subdistal seta reaching far beyond tip of inner terminal spine. Proximal inner seta shorter than segment.

Leg 5 (Fig. 8A, B) confluent with pediger, represented as a single semi-circular expansion. Ancestral basal segment obsolete, represented by long pinnate seta. Ancestral distal segment represented by two equally long elements: outer one setiform, inner one spiniform.

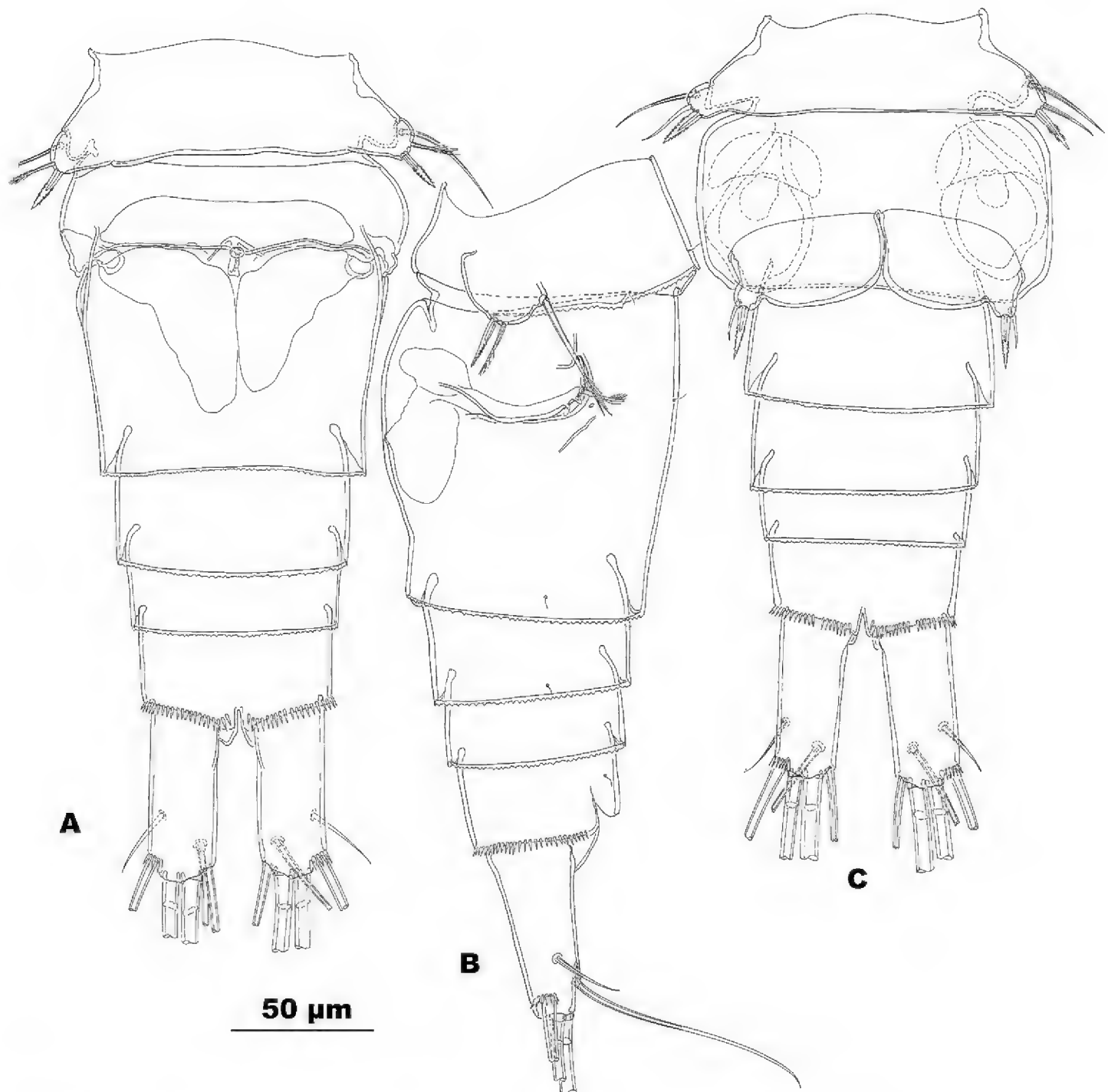
Leg 6 (Fig. 6B) positioned laterally. Valve surface unadorned and bearing three elements on outer caudal edge: outer one setiform, median and medial one minute and truncate. Genital complex with copulatory pore leading to U-shaped duct. Lateral arms straight. Anterior receptacle expanded, with straight frontal margin. Posterior receptacle bi-lobed, expanded far caudally.

*Male.* Prosome and urosome equally long with metasome narrower than in the female (Fig. 7C). Urosomite 2 or pediger 6 (Fig. 8C) wide and short (W/L ratio: 2/1). Posterodorsal fringe of prosomites and posterior fringe of urosomites as in the female. Caudal rami with medial hairy ornamentation and armament as in the female. Body length: 668  $\mu\text{m}$  (allotype, paratypes 665–700  $\mu\text{m}$ ,  $n=5$ ).

Antennule as described for *A. cavicola* in Fiers (2012) with 3 long linguiform aesthetascs on segment 1. Antennary armament and spinule pattern, mouthparts and legs 1–4 as in the female.

Leg 5 (Fig. 8C) as in the female. Leg 6 (Fig. 7 C) represented by large semi-ovate unadorned valve. Outer caudal edge expanded, bearing two elements: outer one setiform, medial one spiniform. The former shorter than the latter.

Variability: In most cases the medial triangular depression of the caudal rami is furnished with two parallel sets of fragile hairs as shown in Fig. 7D. In some specimens an additional row is present. Apart from the ornamentation of the caudal rami a single female shows an aberrant armament of the distal endopodite of right leg 2 with only 3 medial setae instead of 4. Body length and slightly different ratios of the caudal rami and armament are noticeable. Female body lengths range from 720  $\mu\text{m}$  (Well A1 population) to 835  $\mu\text{m}$  (Kéwi population); males from 620 (Well A1 population) to 800  $\mu\text{m}$  (Kéwi population). Length/width ratio of the caudal rami varies between 2.4 to 3.0 with the laterodistal spine 1.2–1.4 and the terminal medial seta 1.6–1.9 times longer than the rami.



**Figure 8.** *Allocyclops pilosus* sp. n. **A** urosome in ventral view **B** urosome in lateral view **C** urosome in ventral view (Female RBINSc COP 10.310 **A, B**; male RBINSc COP 10.312: **C**).

***Allocyclops nudus* sp. n.**

<http://zoobank.org/9231A518-6786-4A71-ACFE-5AD9DE002D62>

Figs 4E, F, J, 5G, H, 10, 11, 12

Syn. *Allocyclops* n sp. [*partim*] in Lagnika et al. 2014b

**Type locality.** Ladjifarani or “Nouveau quartier”, Parakou District, Ouémé drainage basin: Well B6 (details in Table 2).

**Type material.** Holotype female, dissected and mounted on 2 slides, RBINSc COP 10.334A-B, allotype male, dissected and mounted on 2 slides, RBINSc COP 10.335A-B; paratypes: dissected female RBINSc 10.367A-B, preserved material: 7 females, 3 males, 5 juveniles (RBINSc COP 10.333) all collected 29/10/2011; addi-



tional paratypic material (topotypes): 3 females collected 16/01/11 (preserved RBINSc COP 10.352).

**Etymology.** From the Latin adjective “*nudus*” meaning naked and refers to the absence of hairy or spinular ornamentation on the pedigers surface and caudal rami, contrasting the species from *A. spinifer* sp. n. and *A. pilosa* sp. n.

**Additional material.**

(1) Parakou District, Ouémé drainage basin.

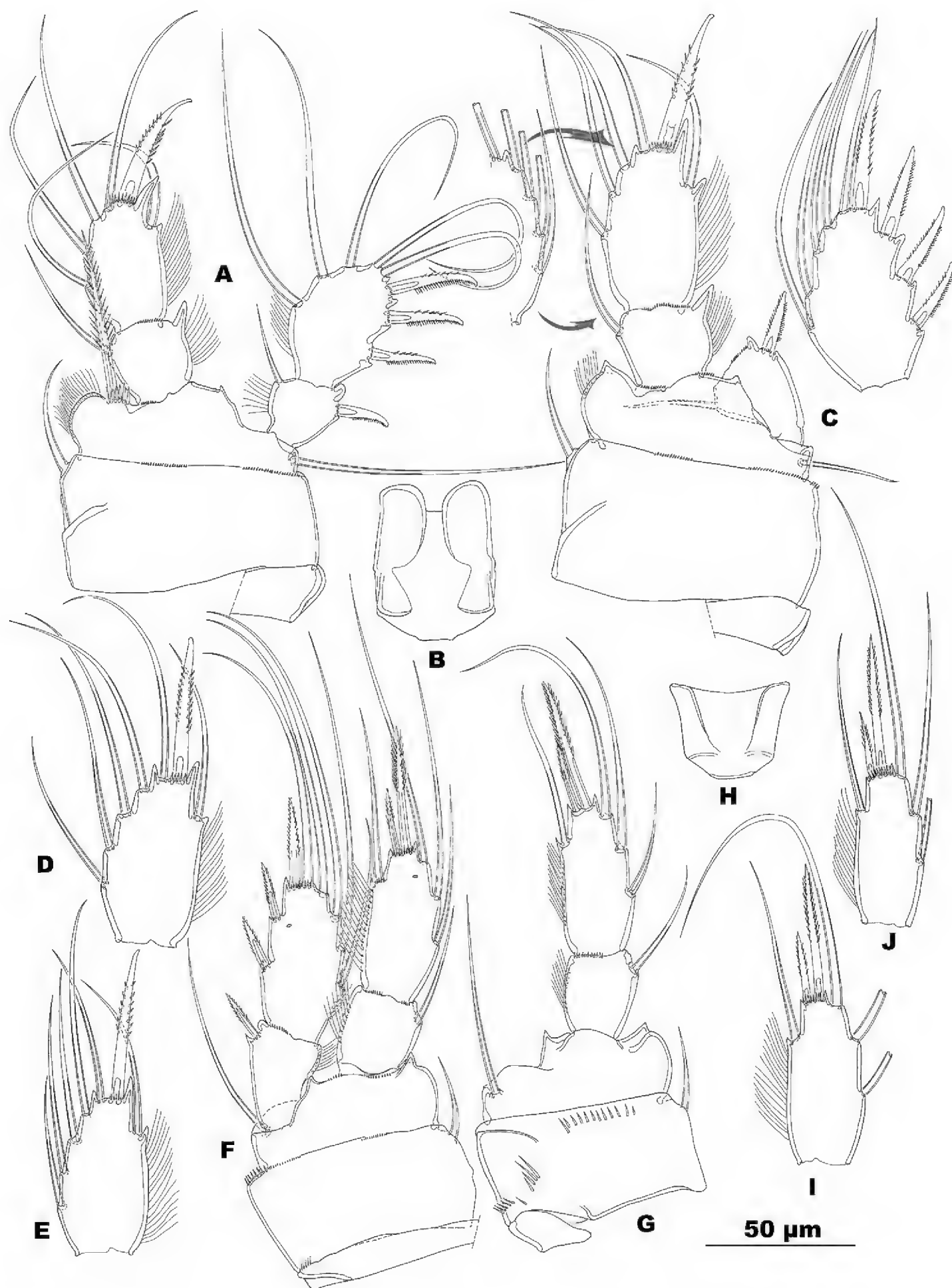
- Well A1: 27/08/2011: 1 ♀, 8 ♂♂ (preserved material RBINSc COP 10.337); 11/01/2011: 4 ♀♀, 1 ♂, 40 juveniles, decomposed condition (preserved material RBINSc COP 10.348); 15/02/2011: 2 ♀♀, 3 ♂♂, 20 juveniles (preserved material RBINSc COP 10.351); 10/07/2012: 48 ♀♀, 12 ♂♂ (preserved material RBINSc COP 10.338);
- Well A5: 16/11/2010: 2 ♂♂, 4 juveniles (preserved material RBINSc COP 10.350);
- Well C3: 30/10/2011: 1 ♂ (dissected male RBINSc COP 10.368); 14/02/2011: 27 ♀♀, 1 ♂ (preserved material RBINSc COP 10.349).

**Description.** *Female:* Body (Fig. 10A) typically cyclopid with prosome longer than urosome (ratio: 1/0.8). Principal body flexure well marked, rather wide. Genital double-somite widest in anterior third, tapering caudally, and as long as widest part. Anal somite with crescent operculum, not expanded. Anal sinus unadorned. Length 900 µm (holotype, paratypes 890–962 µm, n=5). Posterodorsal margins of cephalothorax and pedigers 2–3 straight, of pediger 4 slightly irregular. Urosomite 1 with straight posterodorsal fringe. Posterior margin of genital double-somite and urosomites 4–5 wide, coarsely serrate. Posterior margin of anal somite with uninterrupted row of spinules along ventral and dorsal margins.

Caudal rami cylindrical with triangular depression along anterior half of medial margin, less than 3 times longer than wide (L/W-ratio 1/2.7–2.8). Anterolateral seta, pinnate, short, without spinules near articulation. Posterolateral element shorter than ramus in holotype (ratio: 0.9/1) ranging from 0.8/1–1.0/1 in paratypes), with long and slender spinules along outer side of the stem, pinnate along the inner side. Spinules present at its insertion with ramus. Medial element longer than ramus (ratio: 1.15–1.25/1) and pinnate. Principal terminal setae with breaking plane and pinnate. Dorsal seta 1.3–1.4 times longer than ramus, and articulating on small basal part. Integument of rami unadorned.

Antennule 11-segmented with typical armament, not reaching to posterolateral edge of cephalothorax. Segment 1 with set of slender spinules and set of short ones (Fig. 4 F). Aesthetasc on segment 8 linguiform, reaching beyond middle of segment 9. Aesthetasc on segment 10 filiform, shorter than accompanying seta and reaching halfway terminal segment. Aesthetasc on segment 11 tubular, as long as segments 9–11 combined, and shorter than accompanying seta (Fig. 4E).

Antenna with general appearance and armature as in *A. chappuisi* (see Fiers 2012). Frontal surface of coxobasis with a cluster of 7–9 small spinules near middle of outer margin and a row of slender spinules in proximal half near abexopodal margin (Fig. 5G). Caudal surface of coxobasis with 3 sets of narrow spinules in proximal half: 2 near outer margin, 1 near abexopodal margin (Fig. 5H).



**Figure 9.** *Allocyclops pilosus* sp. n. **A** leg 1, frontal view **B** leg 1 intercoxal sclerite **C** leg 2, frontal view (aberrant number of medial setae on endopodite, normal seta complement shown at the left) **D** distal endopodite segment of leg 3, frontal view **E** idem **F** leg 4, frontal view **G** leg 4 protopodite and endopodite, caudal view **H** leg 4 intercoxal sclerite, frontal view **I-J** distal endopodite segment of leg 4 of other specimens (Females RBINSc COP 10.313: **F, G**; COP 10.310: **A-D, G-H**, COP 10.318: **I**; COP 10.316: **J**; male RBINSc COP 10.312: **E**).



Mouthparts as in preceding species. Maxillary basis (Fig. 4J) prominent and blunt, with set of 4–5 large spinules in middle, increasing in length medially. Accessorial seta robust, with large spinules on both sides of the stem in proximal half, finely serrate along one side in distal half. Armature of proximal endopodite segment and terminal armature element on distal endopodite segment robust, with large spinules in proximal half and finely serrate in distal half on one side of the stem. Terminal seta on distal endopodite segment confluent with segment. Additional elements on distal segment sparsely serrate.

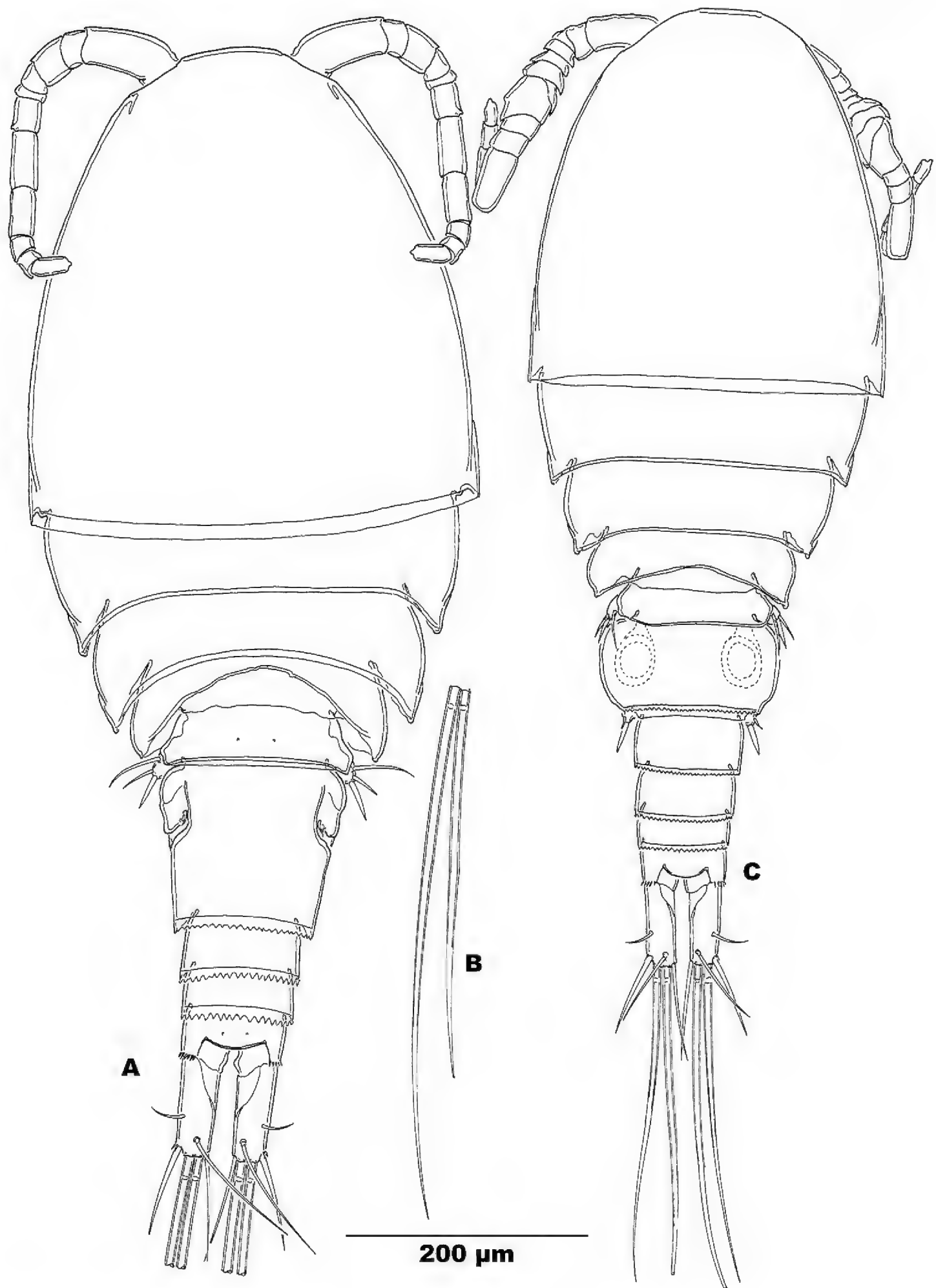
Leg 1–4 protopodite (Fig. 12A–D). Frontal margin of praecoxa with short row of slender spinules near outer corner. Frontal surface of legs 1–4 coxa unadorned except for some minute spinules along distal margin. Caudal surface of leg 1 unadorned, of legs 2 and 3 with some slender spinules near outer proximal corner. Caudal surface of leg 4 coxa with a transverse row of spinules parallel to distal margin and some slender spinules near outer proximal corner. Intercoxal sclerite of legs 1–4 as in preceding species. Medial coxal seta present, pinnate and reaching beyond basis, attending distal margin of proximal endopodite segment in leg 1, and middle of proximal endopodite segment in legs 2 and 3. Medial element somewhat shorter in leg 4. Medial margin of basis of leg 1 crescent, hairy, and with pinnate element reaching beyond proximal endopodite segment. Spinules present at its insertion. Medial margin of basis of legs 2–4 crescent, produced distally in short triangular expansion. Hairy in legs 2–3, naked in leg 4. Outer seta on leg 1 basis as long as exopodite, and as long as first exopodite segment in legs 2–4.

Leg 1–4 rami 2-segmented with general appearance and armament distribution as in preceding species. Frontal and caudal surface of ramal segments unadorned. Proximal segment of leg 4 endopodite inflated caudally (Fig. 12D). Distal endopodite segment of leg 4 2.10–2.15 times longer than wide. Inner terminal spine as long as segment, and 1.8–2.1 times longer than outer spine. Medial setae on second endopodite segment equally long, not reaching beyond inner terminal spine.

Leg 5 (Fig. 11E) with ancestral segments confluent with pediger, represented as a semi-ovate expansion with a discreet truncation distally. Ancestral basal segment represented by a long setiform element. Ancestral distal segment represented by 2 elements: outer one setiform, half as long as medial spiniform element, both inserted on the distal discreet truncation.

Leg 6 (Fig. 11B) typically represented by 3 elements: outer one setiform, middle and medial ones dwarfed, hyaline and blunt. Valves unadorned. Genital complex with frontal and caudal parts of receptacles expanded. The former with undulate frontal margin, the latter with single medioventrally expansion. Copulatory pore leading to U-shaped duct (Fig. 11D). Lateral arms straight.

*Male*: Body narrower than female body (Fig. 10C). Prosome 1.5 times longer than urosome. Principal body flexure wide. Second urosomite (pediger 6) 2 times wider than long. Body length 795  $\mu\text{m}$  (allotype, ranging from 744 to 817 in paratypes). Posterodorsal margins of prosomites and first urosomite narrow and straight. Posterior hyaline fringe margins of urosomite 2 narrow and serrate, of urosomites 3–5 wide and



**Figure 10.** *Allocyclops nudus* sp. n. **A** habitus in dorsal view **B** principal caudal setae of right caudal ramus **C** habitus in dorsal view (Female RBINSc COP 10.334: **A**, **B**; male RBINSc COP 10.335: **C**).



serrate. Anal somite with crescent, not expanded, anal operculum. Anal sinus smooth. Posterior margin of anal somite with uninterrupted row of spinules.

Caudal rami cylindrical with short triangular medial depression in anterior half. L/W-ratio: 2.7/1 (allotype, ranging from 2.7–3.0/1 in other male paratypes). Antero-lateral seta short, pinnate, without spinules at insertion. Distolateral element shorter than ramus (ratio: 0.8–0.9/1) serrate along outer margin, pinnate along inner one. Spinules at insertion present. Terminal medial element longer and dorsal one longer than ramus: 1.15–1.25/1 and 1.25–1.35, respectively. Dorsal seta articulating on basal part. Principal terminal setae with breaking plane and pinnate.

Antennule as described for *A. cavicola* in Fiers 2012. Mouthparts and legs 1–4 as in the female, except for leg 4 endopodite lacking expansion of caudal surface of the proximal segment. Leg 5 (Fig. 11C) with region representing ancestral distal segment more pronounced than in the female. Armature elements as in the female.

Leg 6 (Fig. 11C) represented as large, unadorned valve with caudally produced outer distal edge bearing 2 elements: outer one very short, setiform, medial long, spini-form and serrate.

Variability. Except for slight variation (less than 15 µm) in the body length and the L/W ratio of the caudal rami and its armament, no structural differences were observed in the type series nor in the other populations.

### ***Allocyclops sakitii* sp. n.**

<http://zoobank.org/316EB4BF-2BA4-406E-B289-81CE29B3C34D>

Figs 4G, H, L, 5I, J, 13, 14, 15

**Type locality.** at Addrodji, Lokossa District, Mono Couffo drainage basin: Well P2 (details in Table 1).

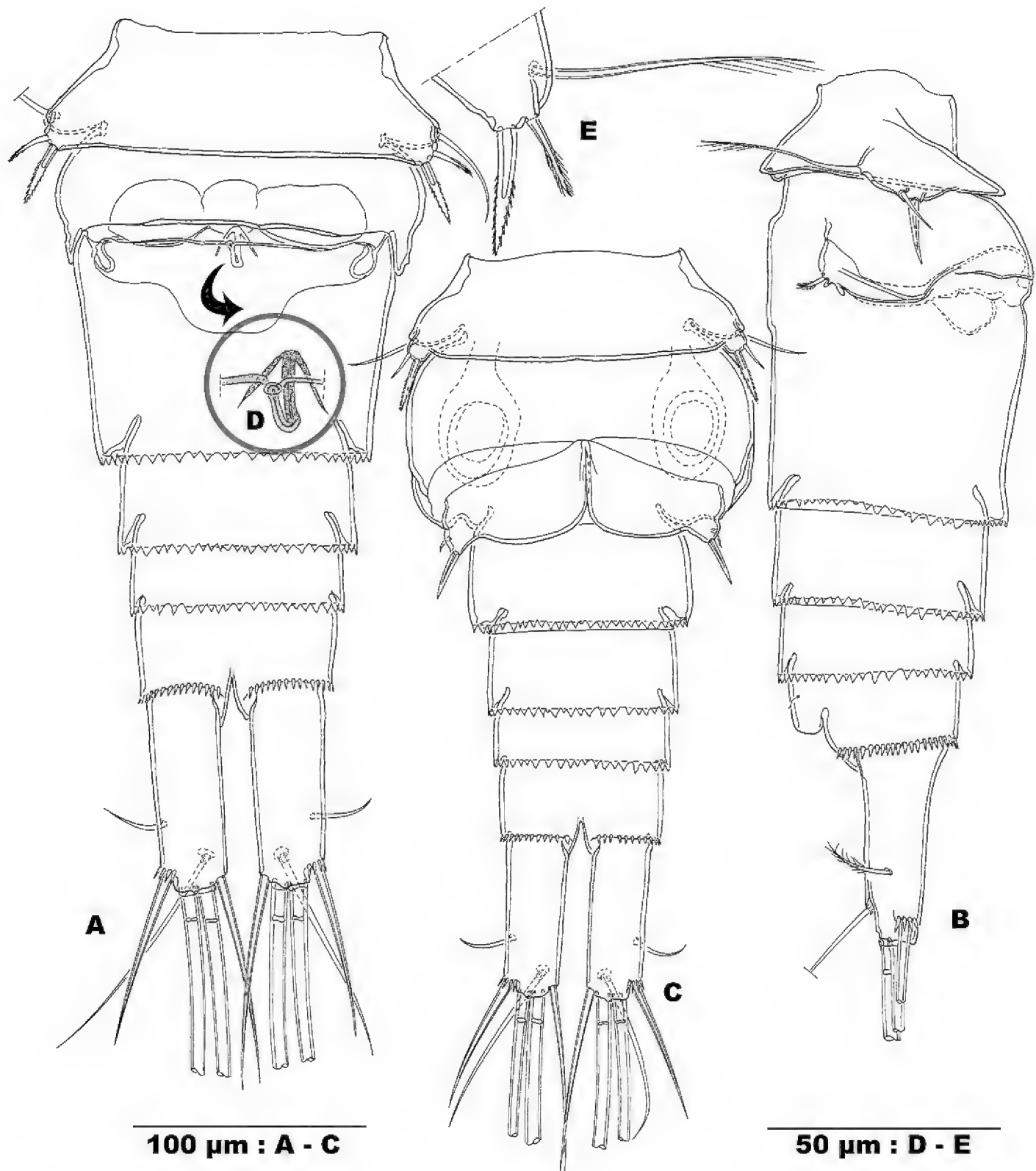
**Type material.** Female holotype, dissected and mounted on 3 slides, RBINSc COP 10.354; allotype male, dissected and mounted on 2 slides, RBINSc COP 10.356; female paratypes dissected: RBINSc COP 10.355A–C, COP 10.357 A, COP 10.358 A–C; 14 females and 5 males preserved (RBINSc COP 10.359), all collected 1–12–2012. Additional paratypic material (topotypic), collected 19/06/2012: 185 females, 15 males (preserved material RBINSc COP 10.360).

**Etymology.** Named after Nestor G. Sakiti who initiated, in collaboration with Claude Boutin, subterranean biology research in Bénin, and supported the junior author initializing his investigations.

### **Additional material.**

(1) Lokossa, Mono District, Mono-Couffo drainage basin:

- Well P6: 17-06-2012: 1 ♀ (preserved material RBINSc COP 10.364); 06/09/2012: 18 ♀♀ 1 ♂ (preserved material RBINSc COP 10.378); Well PM (about 20 m from well P6, cemented, closed and abandoned, and considered here as identical with well P6): 07/01/2012: 65 ♀♀, 4 ♂♂ (dissected ♀ RBINSc COP 10.370A–C; preserved material RBINSc COP 10.365).



**Figure 11.** *Allocyclops nudus* sp. n. **A** urosome in ventral view **B** urosome, lateral view **C** urosome in ventral view **D** copulatory pore and duct **E** leg 5 and outer edge of pediger 5 (Female RBINSc COP 10.334: **A, B, D, E**; male RBINSc COP 10.335: **C**).

- Well P7: 13-06-2012: 74 ♀♀, 4 ♂♂, 2 juveniles (dissected ♀ RBINSc COP 10.369A-C; preserved material RBINSc 10.363);
- Well P9: 11-06-2012: 116 ♀♀, 11 ♂♂, 9 juveniles (preserved material RBINSc COP 10.361); 30-11-2012: 9 ♀♀, 2 ♂♂ (preserved material RBINSc COP 10.362 ).

(2) Abomey-Calavi District, Ouémé drainage basin:

- Well near Campus: 27-02-2013: 24 ♀♀, 3 ♂♂, 1 juvenile (preserved material RBINSc COP 10.366).



**Description.** *Female:* Body (Fig. 13A) typically cyclopoid with prominent prosome (1.8–1.9 times urosome length). Genital double-somite widest in anterior third, and as long as widest part. Posterodorsal fringe of prosomites and urosomite 1 narrow and straight. Posterior fringe of genital double-somite and urosomites 3–4 narrow and discretely serrate (Fig. 14A, B). Anal somite with shallow crescent operculum (Fig. 13C). Anal sinus apparently smooth. Posterior margin of anal somite with uninterrupted row of spinules: rather short dorsally, laterally and along outer half of ventral margin, twice as long along medial half of ventral margin (Fig. 14A). Body length: 833  $\mu\text{m}$  (holotype, paratypes ranging from 807–876  $\mu\text{m}$ ,  $n=5$ ).

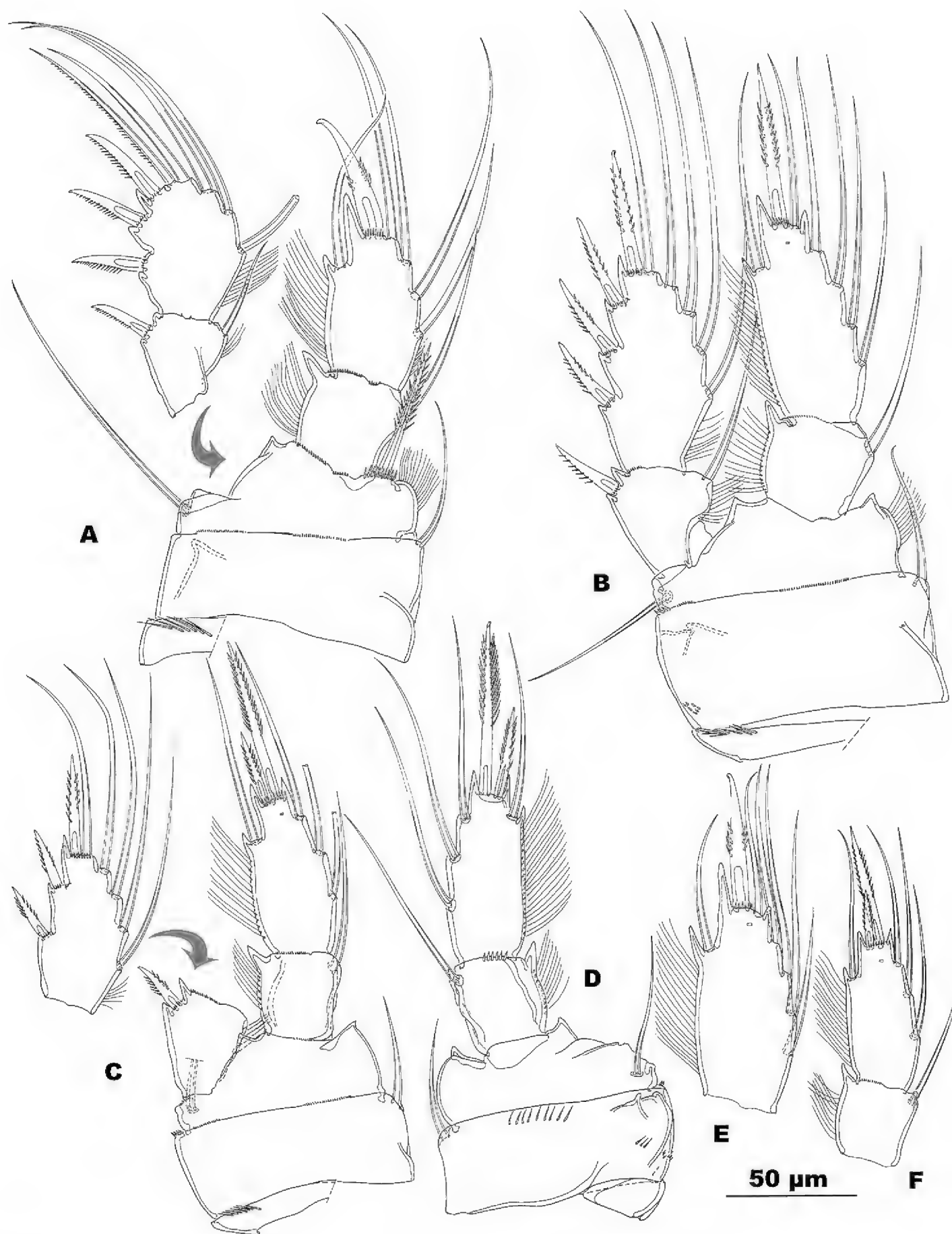
Caudal rami (Fig. 13C) cylindrical, between 2.5 and 2.6 times longer than wide, with triangular medial depression reaching halfway the margin. Integument of caudal rami smooth. Anterolateral seta short and pinnate, without spinules at insertion. Distolateral element equally or slightly longer than ramus (ratio: 1.0–1.1/1), furnished with widely spaced setules on both sides of the stem. Spinules at insertion of distolateral element present. Terminal medial element longer than ramus (ratio: 1.3–1.5/1) and pinnate. Principal terminal setae with breaking plane and pinnate. Dorsal seta, articulating on small basal part, and as long as medial element.

Antennule 11-segmented, not reaching to posterior edge of cephalothorax. Segment 1 with crescent row of spinules in proximal half (Fig. 4H). Aesthetasc on segment 8 linguiform, as long as accompanying seta, and reaching middle of segment 9. Aesthetasc on segment 10 filiform, as long as accompanying seta, and reaching nearly to distal end of terminal segment. Aesthetasc on segment 11 tubular, as long as segments 9–11 combined, and shorter than accompanying seta (Fig. 4G).

Antennary general morphology and armature as in *A. chappuisi*. Frontal surface of coxobasis with a cluster of minute spinules (6–7 spinules) in middle of outer margin and a short transverse set of slender ones in the proximal half bear the abexopodal margin (Fig. 5J). Caudal surface nearly completely naked only furnished with a few slender spinules in the proximal half near the abexopodal margin. (Fig. 5I).

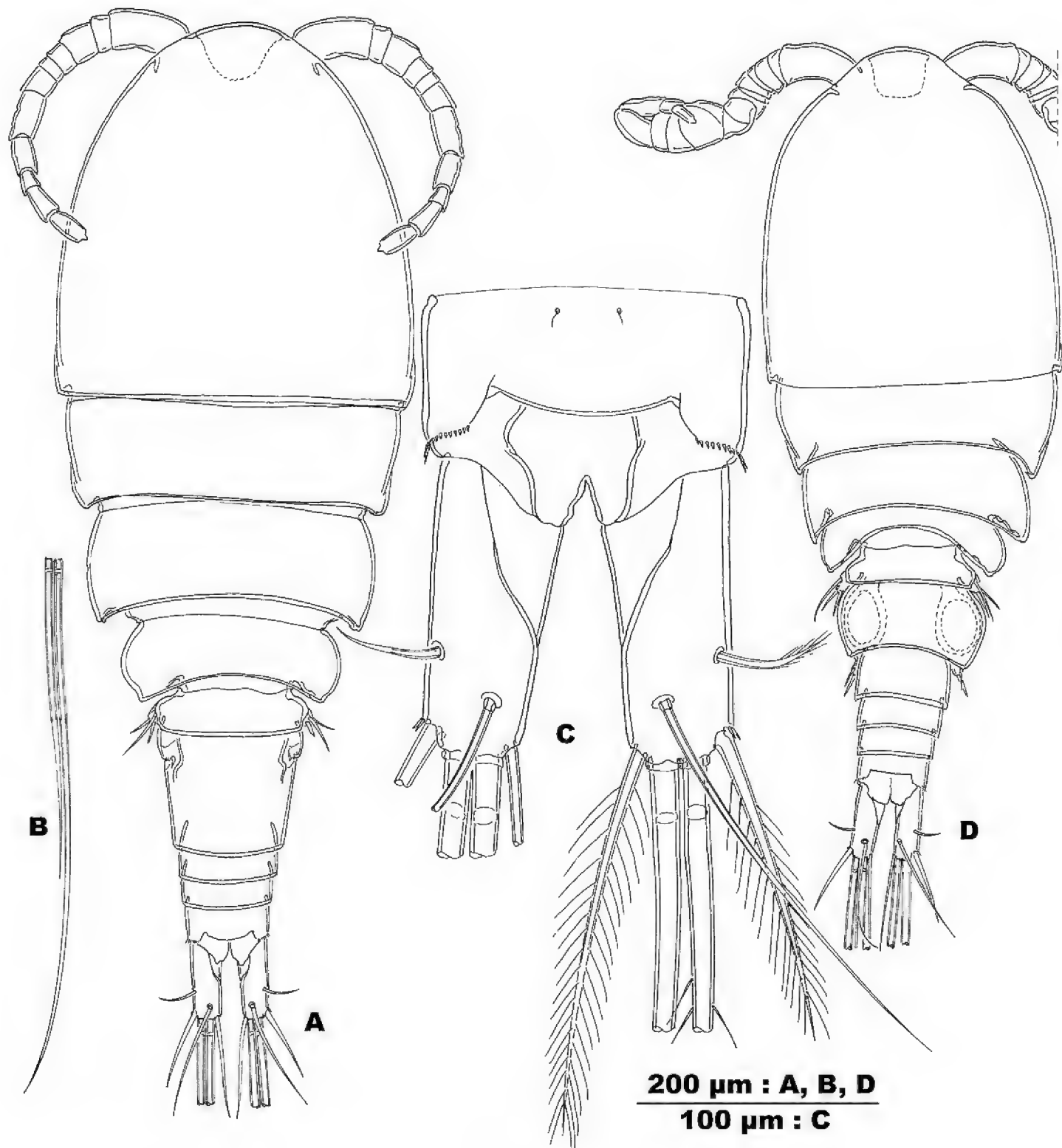
Mandible, maxillule, maxilliped and general aspect of maxilla as in *A. cavicola* and the preceding species. Claw of maxillary basis blunt, armed with 8–9 large spinules, increasing in width and length medially. Claw shorter than accessory element (Fig. 4L). The latter furnished with groups of long spinules on both sides in proximal half and along one side in distal half, besides the finely serrate ornamentation of the distal part of the stem. Both elements on proximal endopodite segment and terminal element on distal segment furnished partially with long spinules along one side of the stem, finely serrate at the opposite side. Additional setae on distal endopodite segment slender, unequal in length.

Leg 1–4 protopodite without ornamentation on praecoxa (Fig. 15A, C, E, F). Frontal surface of coxa unadorned except for the usual minute spinules along distal margin. Caudal coxal surface smooth in leg 1, with some slender and short spinules near outer proximal corner in legs 2 and 3 (Fig. 15D). Caudal surface of leg 4 coxa with 2 small clusters of spinules near outer proximal distal corner and a median row of narrow spinules parallel with distal margin (Fig. 15F). Medial coxal seta present in



**Figure 12.** *Allocyclops nudus* sp. n. **A** leg 1, frontal view **B** leg 2, frontal view **C** leg 4, frontal view **D** leg 4 protopodite and endopodite, caudal view **E** leg 3 distal endopodite segment, frontal view **F** leg 4 endopodite, frontal view (Female RBINSc COP 10.367: **A**, **C**, **E**; Female RBINSc COP 10.334: **B**, **D**; male RBINSc COP 10.335: **E**).

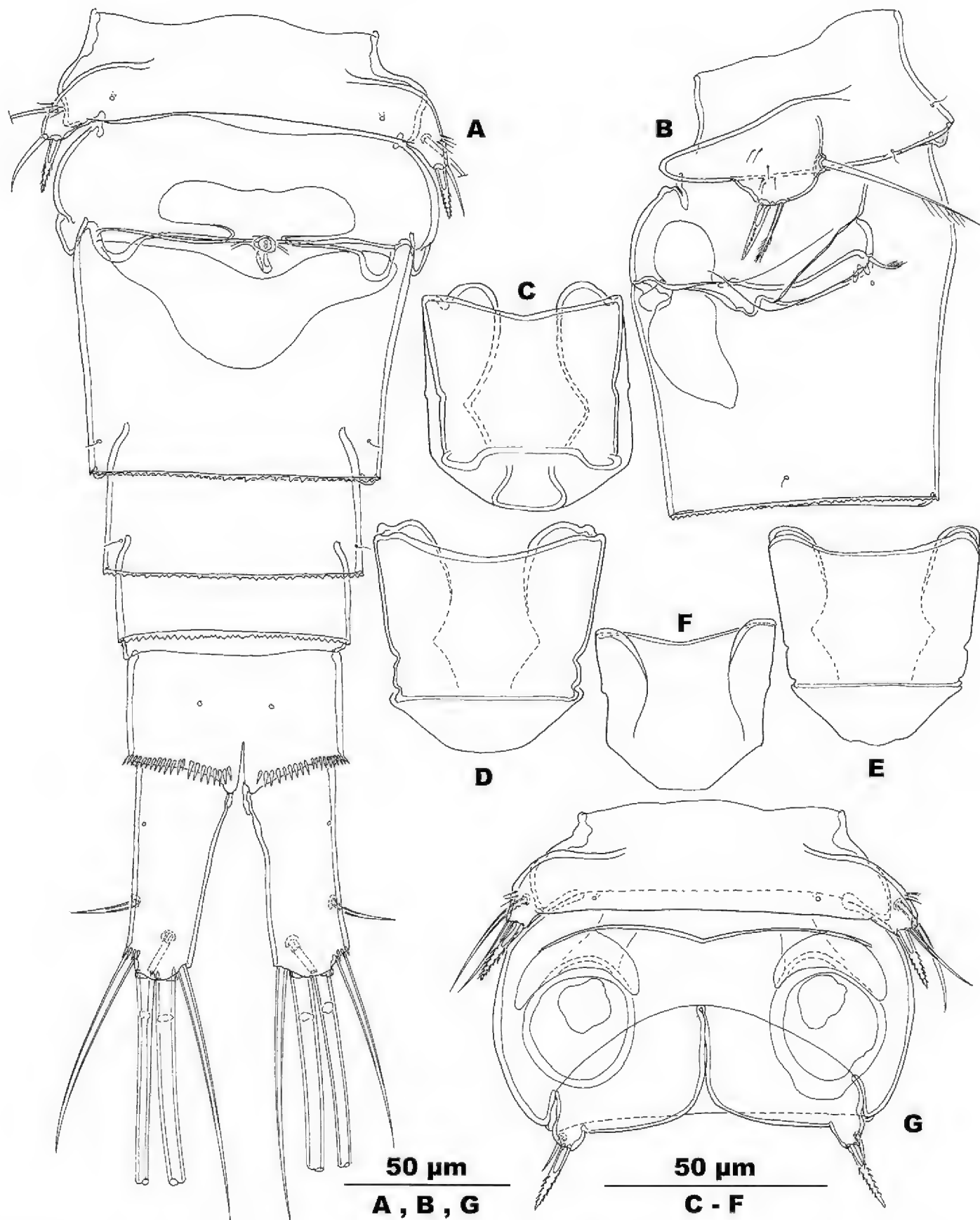




**Figure 13.** *Allocyclops sakitii* sp. n. **A** habitus in dorsal view **B** principal caudal setae of left caudal ramus **C** anal somite and caudal rami, in dorsal view **D** habitus in dorsal view (Female RBINSc 10.357: **A**, **B**; female RBINSc COP 10.354: **C**; male RBINSc COP 10.356: **D**).

all legs, pinnate and reaching to middle of proximal endopodite segment in legs 1–3, but hardly beyond basis in leg 4. Intercoxal sclerites as in preceding species. Basis in leg 1 with long medial spine, reaching to middle of distal endopodite segment and with spinules at insertion. Medial margin of legs 1–3 crescent and hairy, naked in leg 4. Medial distal edge of basis in leg 1 rounded, slightly triangularly produced in legs 2–4. Outer seta on basis of legs 1 and 4 as long as exopodite, of legs 2 and 3 half as long.

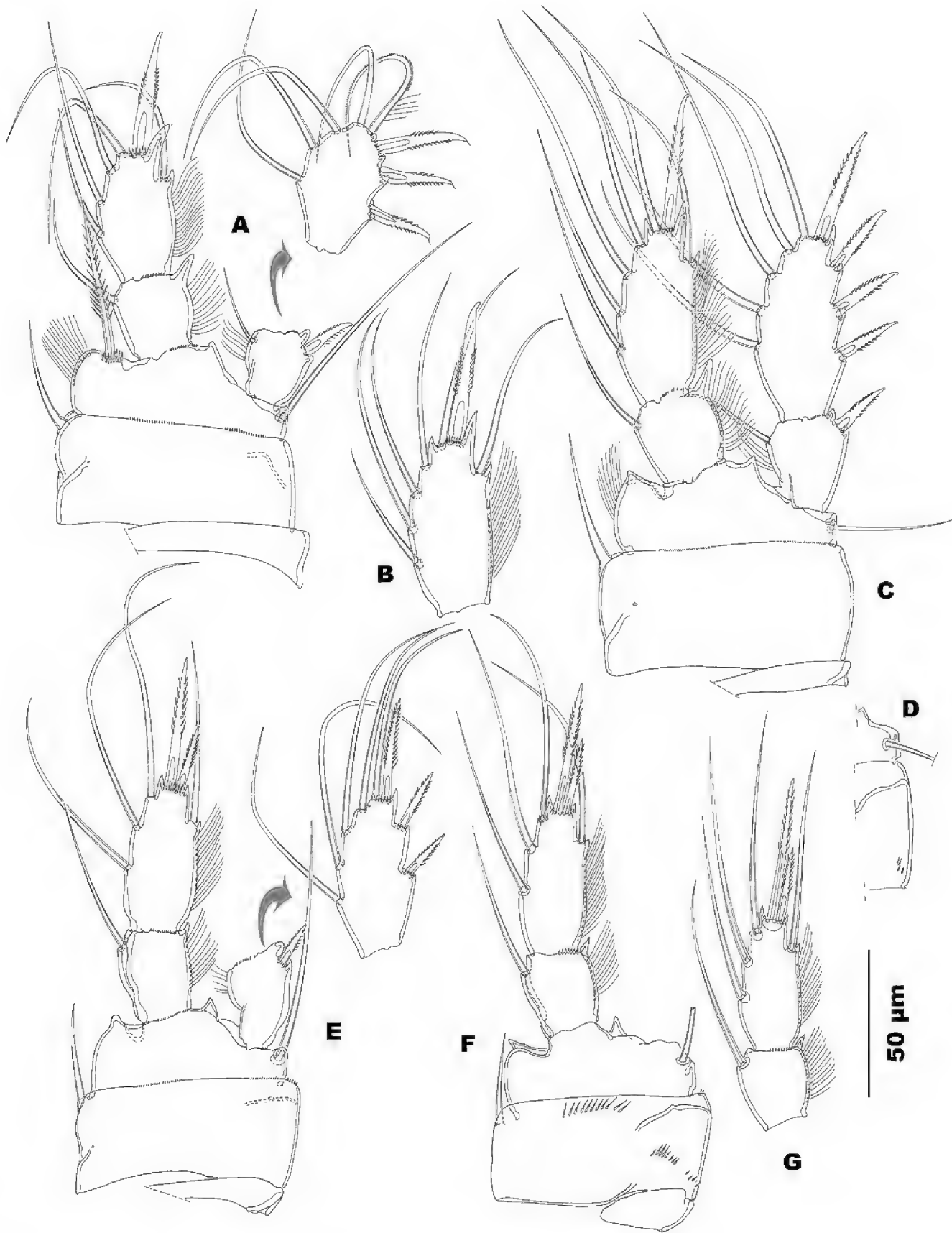
Leg 1–4 rami 2-segmented with general appearance and armament distribution as in preceding species (Fig. 15A–C, E–F). Proximal segment of leg 4 endopodite slightly



**Figure 14.** *Allocyclops sakitii* sp. n. **A** urosome, ventral view **B** pediger 5 and genital double-somite, in lateral view **C** leg 1 intercoxal sclerite, frontal view **D** leg 2 intercoxal sclerite, frontal view **E** leg 3 intercoxal sclerite, frontal view **F** leg 4 intercoxal sclerite, frontal view **G** pediger 5 and urosomite 2 in ventral view (Female RBINSc COP 10.355: **A, B**; COP 10.358: **C–F**; male RBINSc COP 10.356: **G**).

expanded caudally. Distal endopodite segment of leg 4 2.2–2.4 times longer than wide. Inner terminal spine shorter than segment (ratio: 0.9/1), outer spine half as long as inner one. Medial setae on distal endopodite segment of leg 4 reaching distinctly beyond longest terminal spine.





**Figure 15.** *Allocyclops sakitii* sp. n. **A** leg 1, frontal view **B** distal endopodite segment of leg 2, frontal view **C** leg 3, frontal view **D** Outer region of coxa and basis of leg 3, caudal view **E** leg 4, frontal view **F** leg 4 protopodite and endopodite, caudal view **G** leg 4 endopodite, caudal view (Female RBINSc COP 10.355: **A–C, F**; COP 10.358: **D, E**; male RBINSc COP 10.356: **G**).

Leg 5 (Fig. 14A, B) confluent with pediger, represented as a semi-circular expansion bearing 3 elements. Ancestral basal segment represented by long setiform element, ancestral distal segment by two equally long elements: outer one setiform, inner one spiniform. Surface of leg 5 expansion with some short and hairy-like spinules.

Leg 6 (Fig. 14B) located laterally on genital double-somite, typically with 3 elements: outer one setiform, middle and medial one dwarfed, hyaline and blunt. Valve unadorned. Genital complex with small ovate anterior receptacle. Caudally expanded receptacle with single medioventral lobe. Copulatory pore leading to U-shaped duct. Lateral arms straight.

*Male*: General appearance of body as in the female with prosome 1.5 times longer than urosome. The latter with pediger 6 half as long as wide (Fig. 14G). Posterodorsal fringes of prosomite and first urosomite, and posterior fringes of urosomites as in the female. Body length: 676  $\mu\text{m}$  (allotype and other male paratypes ranging between 650 and 695  $\mu\text{m}$ ;  $n=4$ ).

Caudal rami 2.5–2.7 times longer than wide, distolateral element 1–1.15 times longer than caudal rami, and terminal medial element 1.30–1.45 times longer than ramus.

Antennule as described for *A. cavicola* in Fiers (2012). Mouthparts and legs as in the female but proximal endopodite segment of leg 4 without expansion.

Leg 5 (Fig. 14G) with general appearance and integumentary ornamentation as in the female, but with outer setiform element on distal segment vestige longer than inner spiniform element.

Leg 6 vestige (Fig. 14G) large, with protruded outer distal edge, bearing 2 elements: outer one setiform, half as long as inner one. The latter spiniform. Surface of valve unadorned.

Variability: Apart from slight variation in body length and L/W-ratio of the caudal rami and the setae on the caudal rami, no structural variability was observed.

## Discussion

### Differential diagnoses

The cyclopoid genus *Allocyclops* originally erected by Kiefer (1932) and recently redefined (Fiers 2012) corals four species with three African representatives: *A. chappuisi* Kiefer, 1932, *A. cavicola* Chappuis, 1951 and *A. beadleii* (Lindberg, 1956) and one Central-American (*A. botosaneanui* Pleša, 1981). The latter which deviates in many aspects from its three congeners has been tentatively retained in the genus but will certainly be removed when its affinities to the South and North American cyclopines become clarified (Fiers 2012). The three known African representatives are described from sub-Saharan localities located in the tropical savannah region of continental Africa (Peel et al. 2007): *A. chappuisi* Kiefer, 1932 from Ivory Coast (see Chappuis 1934), *A. cavicola* Chappuis, 1951 from Bas-Congo in the Democratic Republic of Congo (see Leleup 1956), and *A. beadleii* (Lindberg, 1956) from Uganda.

An unidentified cyclopine attributed to *Allocyclops* was reported from Morocco (Tuekam Kayo et al. 2012). The specimens have been re-examined by the senior author (35 ♀♀, 1 ♂: catalogued: RBINSc COP 9403, COP 9406, COP 10.132). They can, however, not be assigned to the genus *Allocyclops* but seem to be affiliated with *Metacyclops* Kiefer, 1927.

Among the 4 species described here, *A. nudus* sp. n. resembles most closely *A. chappuisi*, type of the genus, and can be easily confounded with the latter. *A. nudus* sp. n. is however more robust and distinctly larger than *A. chappuisi*. Females of the former measure 895–962  $\mu\text{m}$  and males 744–817  $\mu\text{m}$  whereas females and males of *A. chappuisi* measure 720–740  $\mu\text{m}$  and 650  $\mu\text{m}$ , respectively (Kiefer 1932; 1934). The laterodistal spine on the endopodite of leg 4 is less than half the length of the mediodistal element while in *A. chappuisi* it reaches slightly beyond the middle of the inner spine. The most obvious difference between both species are the proportional lengths of the middle seta and medial spine of leg 5 (in both sexes) and leg 6 of their respective males. In *A. nudus* sp. n. the medial spiniform element is distinctly longer than the middle seta in leg 5 and leg 6 whereas in *A. chappuisi* the female leg 5 medial spine is shorter than the middle one, and equally long in the male leg 5 and leg 6.

As for *A. nudus* sp. n., *A. sakitii* sp. n. resembles *A. chappuisi* in most aspects. *A. sakitii* sp. n. differs from the latter by the larger body dimensions ( $\text{♀}$ : 800–875  $\mu\text{m}$ ,  $\text{♂}$ : 650–695  $\mu\text{m}$  *versus*  $\text{♀}$ : 720–740  $\mu\text{m}$ ,  $\text{♂}$ : 650  $\mu\text{m}$ ), the longer caudal rami (L/W:  $\text{♀}$  2.50–2.65 *versus* 2.33) and the longer distolateral element of the caudal rami ( $>$  than ramal length *versus*  $<$  than ramus). *A. sakitii* sp. n. might also be distinguishable from *A. chappuisi* by the presence of the hairy ornamentation on the lateral margin of pediger 5. However, presence or absence of ornamentation on pediger 5 in *A. chappuisi* could not be explicitly confirmed because of the condition of the material (see Fiers 2012).

*A. pilosus* sp. n. and *A. spinifer* sp. n. are readily distinguishable from all the other *Allocyclops* species by the presence of ornamentation on the caudal rami: pilose in *A. pilosus* sp. n., serrate in *A. spinifer* sp. n. The pilose structures on the rami of *A. pilosus* sp. n. remind to some extent the ornamentation on the caudal rami of *A. cavicola* but is quite different in the former because of the linear arrangement of the setules and their location restricted to the medial margin of the rami *versus* the dorsal, lateral and medial location, and the more abundant presence of the structures on the rami of *A. cavicola*.

The morphology of four new species described herein concerts completely with the amended diagnosis of *Allocyclops* as proposed by Fiers (2012). On the basis of their morphology (*i.e.* body shape, leg armament, buccal appendages) Fiers (2012) surmised a close relationship between *Allocyclops* and certain African *Metacyclops* species. The new additions neither dismiss nor support this assumption. The lack of detailed information on the morphology of the African *Metacyclops* species stamps such coherent analyses.

### Key to the African species of the genus *Allocyclops*, applicable for both genders

- |   |  |                          |
|---|--|--------------------------|
| 1 | Leg 4 distal exopodite segment with 5 medial setae; Caudal rami with medial seta twice as long as ramus, at most.....                              | 2                        |
| – | Leg 4 distal exopodite segment with 4 medial setae; Caudal rami with medial seta 2.4–2.5 times longer than ramus.....                              | <b><i>A. beadlei</i></b> |
| 2 | Caudal rami 3 times longer than wide at the most (between 2.3–3.0/1); Medial seta on caudal rami 1 to 1.5 times as long as ramus, at the most..... | 3                        |



- Caudal rami more than 3 times longer than wide (generally 3.15/1); Medial seta on caudal rami 2 times as long as ramus..... ***A. cavicola***
- 3 Pediger 5 without ornamentation on lateral and ventrolateral margins..... **4**
- Pediger 5 furnished with either spinules or slender setules on lateral and ventrolateral margins..... **6**
- 4 Medial margin of caudal rami with 2 or 3 transverse rows of thin hairs (visible only when rami are observed dorsally); Leg 4 terminal endopodite segment 2.2–2.3 times longer than wide; Distolateral seta longer than caudal rami (1/1.2–1.3) ..... ***A. pilosus* sp. n.**
- Medial margin of caudal rami without ornamentation; Leg 4 terminal endopodite segment 2.1 times longer than wide at the most; Distolateral seta as long as caudal rami at the most (1/0.8–1.0) ..... **5**
- 5 Caudal rami 2.7–2.8 times longer than wide; Dorsal seta on caudal rami 1.5 times longer than ramus; Medial spine of leg 5 1.5 times longer than middle setiform element ..... ***A. nudus* sp. n.**
- Caudal rami 2.5 times longer than wide at the most; Dorsal seta on caudal rami less than 1.5 times longer than ramus; Medial spine of leg 5 shorter than middle setiform element ..... ***A. chappuisi***
- 6 Lateral and ventrolateral margin of pediger 5 with cluster of spinules; Surface of caudal rami and leg 4 ramal segments with diffuse pattern of minute spinules ..... ***A. spinifer* sp. n.**
- Lateral and ventrolateral margin of pediger 5 with cluster of fine hair-like setules; surface of caudal rami and leg 4 ramal segments unadorned.....  
..... ***A. sakitii* sp. n.**

## Occurrence

Of the 52 regularly visited wells, 40 (77%) were populated with a copepod fauna: 39 exclusively with Cyclopidae, 1 exclusively with Harpacticoida. In 13 wells, i.e. 3 in the districts of Lokossa, Pobè, and Parakou and the 4 wells at Porto-Novo, representatives of the genus *Allocyclops* were the only cyclopines found (Tables 1–4: exclusively dark grey background cells). All other wells accommodate a more diverse fauna with species of the genera *Afrocylops*, *Thermocylops* and *Mesocylops* as the most frequently observed taxa. *Allocyclops* species rarely co-occurred with another cyclopine in the districts of Parakou (3 of the 16 wells harbouring copepods) and of Lokossa (1 of 10 wells). In contrast, *Allocyclops* was found living among other copepods in 5 of the 10 wells in the district of Pobè.

Co-occurrence of two species of *Allocyclops* has been registered in 3 wells: *A. nudus* sp. n. and *A. pilosus* sp. n. in A1 and B6 (Parakou district) and *A. spinifer* sp. n. and *A. pilosus* sp. n. in well Pb6 (Pobè district).

*A. pilosus* sp. n. is the most widespread species. Reported from 16 wells, its presence in the northern district of the study area (Parakou) and the southern districts (Pobè, Porto-Novo, Kétou) spans the entire Ouémé drainage basin. *A. spinifer* sp. n. appears



to be restricted to the district of Pobè but was also detected in the occasionally visited well at Zogbodomè. It might be that the species has a preference to the southern and less elevated parts of central Bénin. Pobè and Zogbodomé are located in the Ouémé drainage basin. The occurrence of *A. nudus* sp. n. is restricted to the district of Parakou, in the northern and most elevated part of the Ouémé drainage basin. *Allocyclops sakitii* sp. n. occurs only near Lokossa located in the drainage basin flooded by the rivers Mono and Couffo. The presence of the latter species in the occasionally visited well at Abomey-Calavi (located at the western limits of the Ouémé basin) is probably a result of the mixing of the waters from the Ouémé and Mono-Couffo basins in the coastal zone.

### Subsoil characteristics

Bénin is well endowed with a dense river system flowing from north to south in central and southern Bénin (Ouémé and Mono-Couffo basins). Drainages in northern Bénin (roughly above 10° N) form tributaries of the large West-African rivers and run north-west (Volta basin) and north-east (Niger basin). Rivers are particularly subject of a flashy response to rainfall. They retain most of the year a low water level (large rivers) or disappear completely at the surface (many second rank tributaries). Villages have always been dependent on presence of a sufficient supply of groundwater during the long periods of drought for which human made hang-dug-wells and natural springs in the laterite soils have been the solution.

Laterite soils are subsoils of equatorial forests, the savannahs of humid tropical regions and of the Sahelian steppes (Tardy et al. 1991; Tardy 1997). They are a product of intensive weathering of the basement rocks and show distinct horizons. Their extension varies from 5 to 10 m below the ground level with the general translocation of clays towards the base (Bonsor et al. 2013). The clayish base layers support a primary aquifer with a regional extension. Depending on the local topography, a narrow to wide zone stretches between the laterite and the basement rock on which the deeper aquifer (vadose) develops (Alassane et al. 2010; MacDonald et al. 2012).

The hydrodynamic properties of a laterite aquifer are characterized by extreme variations with rapid lateral throughflow in the upper horizon during the wet season, and a narrow range of natural groundwater levels for much of the year. The majority of wells studied herein show this rather shallow to low water level (Tables 1–4: water-level fluctuation).

Members of the genus *Allocyclops* display a curious combination of conservative and advanced features. The combination of the large body size, the fully developed mouthparts and the complete armature compliment on the legs is in contrast with the general image of a subterranean cyclopine. The 11-segmented antennules and the 2-segmented rami of the legs however, are in accordance with a subterranean life style. It is assumed (Fiers 2012) that *Allocyclops* branched off directly from an epigean stock. The harsh and extreme variable environmental epigean circumstances may have been the main forces which favored the invasion of the subsoil aquifer by the ancestor.



Thus far, only *A. chappuisi* has been explicitly reported from a laterite spring (Kiefer 1932; Chappuis 1934). *A. cavicola* was discovered in a cave formed in a limestone outcrop of the laterite surroundings in Bas-Congo (Chappuis 1951; Leleup 1956). The poorly known *A. beadlei* was found in a marshy environment in Uganda (Lindberg 1956). The latter, clearly in a far state of decomposition, was possibly washed out of the laterite deck beds. With the addition of the four herein described species, it appears that the members of the genus *Allocyclops* are particularly well adapted to live in the shallow and variable environment of laterite groundwater. The genus is, as far as conclusions can be drawn, a typical African sub-Saharan taxon (taking in consideration the temporary assignment of *A. botosaneanui*).

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